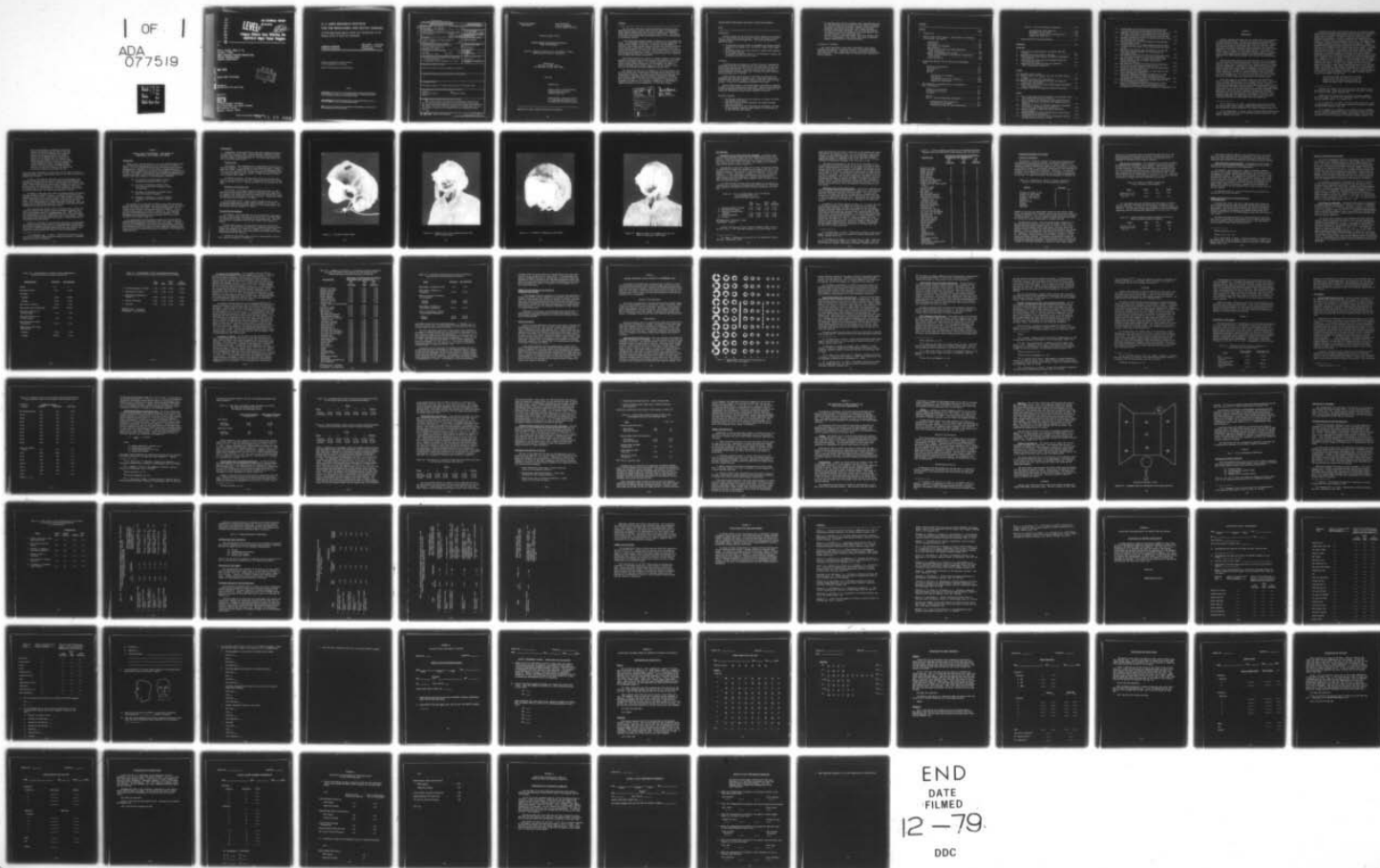


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by

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and Albert L. Kubala
HUMAN RESOURCES RESEARCH ORGANIZATION
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May 1979

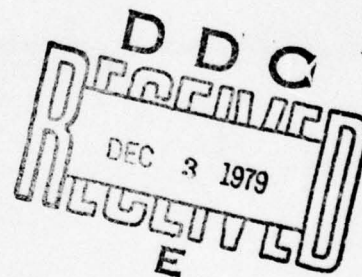
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FATIGUE EFFECTS FROM WEARING THE AN/PVS-5
NIGHT VISION GOGGLES

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FOREWORD

The Fort Hood Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI) provides support to Headquarters, TCATA (TRADOC Combined Arms Test Activity; formerly called MASSTER--Modern Army Selected Systems Test Evaluation and Review). This support is provided by assessing human performance aspects in field evaluations of man/weapons systems.

A war using modern weapons systems is likely to be both intense and short. US man/weapons systems must be effective enough, immediately, to offset greater numbers of an enemy. Cost-effective procurement of improved or new combat systems requires testing that includes evaluation of the systems in operational settings similar to those in which the systems are intended to be used, with troops representative of those who would be using the systems in combat. The doctrine, tactics, and training packages associated with the systems being evaluated must themselves also be tested and refined as necessary.

This report presents the results of studies designed to investigate problems of discomfort and fatigue resulting from extensive use of the AN/PVS-5 Night Vision Goggles. The studies specifically explore the nature of the problems encountered with the goggles, the types of abilities degraded after lengthy goggle use, and the promise of solutions to the problems which were suggested by goggle users.

ARI research in this area is conducted as an in-house effort, and as joint efforts with organizations possessing unique capabilities for human factors research. The research described in this report was done by personnel of the Human Resources Research Organization (HumRRO), under contract DAHCl9-75-C-0025, monitored by personnel from the ARI Fort Hood Field Unit. This research is responsive to the special requirements of TCATA and the objectives of RDTE Project 2Q763743A775, "Human Performance in Field Assessment," FY 1978 Work Program.

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Joseph Zeilner
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Technical Director

FATIGUE EFFECTS FROM WEARING THE AN/PVS-5 NIGHT VISION GOGGLES

BRIEF

Requirement:

The work carried out in this study is that referred to in paragraph 2.2.5 of the Statement of Work dated 24 February 1977 under the title "Fatigue Effects of CAV NAV Goggle Use." The following objectives guided the study:

- To determine the exact nature of discomfort and fatigue problems resulting from lengthy use of the AN/PVS-5 Night Vision Goggle (NVG).
- To identify those motor skills which are significantly degraded after lengthy NVG use.
- To tentatively identify remedies to the discomfort, fatigue, and performance problems that are found.

Procedure:

A questionnaire was designed to provide information regarding the usefulness of the NVG, the physiological locus and nature of any discomfort experienced by the user, and the ease with which the NVG could be positioned and adjusted. Twenty-one aviators and six motorcycle scouts completed the questionnaire upon returning from night maneuvers involving lengthy use of the NVG.

Visual and motor skill decrements resulting from NVG wear were determined from selected performance tests. These were administered to aviators before and after flights in which the NVG were used for long periods. A total of 34 individuals performed on the tests.

Several modifications to the helmet/goggle configuration suggested by users to relieve fatigue were constructed. Thirty aviators performed a head-turning exercise with different configurations in position, and rated each configuration along several dimensions afterward.

Principal Findings:

- The NVG were preferred over the naked eye for almost all night-time maneuvers and tasks.
- Over 90% of users reported discomfort and fatigue problems related to NVG wear.
- Minor difficulties in NVG positioning and adjustment, and part of the discomfort reported, seem related to the interface of the NVG with the SPH-4 helmet.

- As experience with the NVG increased, users found them more useful for performing tasks and maneuvers, less rapidly fatiguing, and easier to position and adjust. However, even the most experienced users reported discomfort and fatigue problems.
- Eye-hand coordination decrements, lack of corrective behavior in response to errors, and evidence of prolonged physical exertion were apparent after lengthy NVG wear.
- Raising the brow of the SPH-4 helmet, along with adding a chin-cup or a counterweight to the helmet, were rated as promising physical modifications to relieve discomfort.

Utilization of Findings:

The effort described in this report constitutes a step toward defining and ultimately alleviating discomfort and fatigue problems resulting from NVG wear. Additional research is definitely indicated. Final solutions to the problems should be developed from a synthesis of related findings.

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Chapter 1

INTRODUCTION

Military planners anticipate that any future wars will be fought on an around-the-clock basis. Virtually all activities are expected to continue through the night, and the many problems attendant to performing under low levels of illumination will thus come into play. While each individual soldier faces difficulties unique to this situation, conditions of reduced illumination place particularly pronounced visual demands upon the aviator of rotary winged aircraft. Such tasks as terrain flight, confined area operations, landing, takeoff, reconnaissance, target acquisition and ordnance delivery require physiomotor responses that depend almost entirely upon visually perceived information.

Although extensive training on night maneuvers can to some degree allow the aviator to develop techniques to cope with the low-illumination situation, physical limitations of the visual system do not permit complete compensation. Sophisticated light amplification devices have thus been produced to assist night performance, one of which is the AN/PVS-5 Night Vision Goggle (NVG) as developed by the US Army Night Vision Laboratory. The NVG is a battery-powered binocular viewing device which weighs 31 ounces (.88 kg); it allows a 40° field of view with unity magnification. For use in rotary wing aircraft, the NVG is mounted on an SPH-4 helmet with snaps and velcro attached straps.

While the goggle is an extremely effective light amplification device, certain problems have arisen in relation to its use. One early concern involved the possibility of eye damage; however, carefully controlled investigations found associated visual afterimages to be of brief duration, and without long-term effect.¹ Another more significant problem is that of loss of visual resolution and depth perception during goggle wear. Wiley and Holly² conducted various acuity and depth perception tests and concluded that while the NVG afford only 20/70 Snellen acuity, and depth perception at distances of 500 feet is substantially degraded, the goggle does allow rotary wing flight under conditions which would be prohibitive with the unaided eye.

¹ D. D. Glick and C. E. Moser. *Afterimages Associated with Using the AN/PVS-5 Night Vision Goggle*, USAARL Letter Report-75-1-1-7-1, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, August 1975.

² R. W. Wiley and F. F. Holly. *Vision With the AN/PVS-5 Night Vision Goggles*, ARL-76-DA 1498, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, April 1976.

A persisting problem associated with NVG use over extended periods of time involves discomfort and fatigue resulting from both the goggle's weight and poor mounting compatibility with the standard 3.4 pound helmet used by aviators. In reports of initial tests conducted to determine the potential of the NVG, discomfort and fatigue were mentioned as negative factors associated with its use. For example, while conducting a series of night maneuvers, USAF Tactical Air Command found the goggle unsatisfactory from a human factors standpoint. Primary problems were fatigue and general discomfort which were reported by the majority of crew members of all aircraft used in the study.³ In another test involving a variety of helicopter flying tasks, several fatigue problems were reported.⁴ Among the more serious of these were muscle strain due to the uneven weight distribution caused by the goggle, eyestrain, and pilots' expressions of concern for possible injury during abrupt landings because of possible twisting in the helmet/goggle mounting. Flights of 30 to 45 minutes duration were found to be acceptable with continuous use of the goggle. It was recommended that the goggle's weight be reduced or redistributed to prevent excessive strain and to increase user comfort. Further, user comments on the total helmet/goggle system after a night target detection/recognition test included reports of discomfort, neck fatigue and forehead pain, some pressure on cheeks, and general muscular fatigue perhaps due to the unaccustomed helmet position and the weight of the NVG.⁵ Finally, among the results of a study on aviator performance with the goggle, Sanders, Kimball, Frezell, and Hoffman⁶ reported that:

Data from the study indicated that the primary design problem with the PVS-5's was that the weight was not distributed equally across the helmet and helmet liner. The result was that

³Tactical Air Command, US Air Force Tactical Air Warfare Center, Eglin AFB, Florida. *Helmet-mounted Night Vision Binocular*, TAC Test No. 71A-102S, Final Report, February 1972.

⁴Modern Selected Systems Test Evaluation and Review (MASSTER), Fort Hood, Texas. *Report of User Evaluation, AN/PVS-5 Night Vision Goggles*, MASSTER Test No. 154, January 1973.

⁵R. W. Bauer and G. D. Petit. *Air Scout Night Goggle Test*, Technical Memorandum 14-74, US Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, July 1974.

⁶M. G. Sanders, K. A. Kimball, T. L. Frezell, and M. A. Hoffman. *Aviator Performance Measurement During Low Altitude Rotary Wing Flight with the AN/PVS-5 Night Vision Goggles*, USAARL Report 76-10, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, December 1975.

most of the pressure or weight was on the face (cheeks and forehead) and the nape of the neck. Most of the pilots recommended that additional pressure relief pads be used on the cheeks. Some of the recommendations for improving the mounting of the goggles were (1) transfer the weight from the cheeks to the top of the helmet (2) use supporting frame to keep the goggles from sliding forward, (3) mount the goggles permanently to the helmet visor and swing them down for use, (4) get a new frame for the lenses, and (5) keep the frame from touching the face.

Due to the above conditions the pilots felt that if asked to go on an extended mission, the average maximum length of time they could wear the goggles was 2.25 hours.

In light of the problems with weight and the helmet/goggle configuration cited above and elsewhere,⁷ a Human Resources Need (HRN) statement was submitted by the 6th US Cavalry Brigade (Air Combat) [6th ACCB]. Therein they reported serious pilot fatigue after only two hours of goggle wear, due predominantly to pressure loading on the facial bones and strain on the neck muscles. It was stated that such fatigue may preclude the pilots from safely operating their aircraft.

Accordingly, steps were first taken to carefully define the fatigue problems incident to AN/PVS-5 NVG use. A detailed questionnaire was composed to aid the effort to identify some common sources of complaint, and was administered to personnel assigned to the 6th ACCB at Fort Hood, Texas. Both human comfort and convenience considerations and their effect on the accomplishment of flying tasks were considered. Thus, the primary goal of this initial phase was to provide a more detailed understanding of the specific areas of user concern.

With these concerns in mind, tests of vision and motor skills were devised to determine the types of actual performance decrement which result from fatigue related to extended goggle use. These tests were then administered to aviators immediately upon their return from maneuvers which required long and uninterrupted wear of the goggles. Results were compared with these obtained from a group of aviators who had not flown before they were tested.

Finally, in an effort to find potential solutions to the discomfort and fatigue problems, modifications to the helmet/goggle configuration which had been suggested by users were constructed and rated for comfort by aviators. Various promising modifications were then combined, and additional comfort ratings were taken for these configurations.

⁷E. M. Haverland and J. L. Maxey. *Problems in Helicopter Gunnery*, ARI Technical Report, Human Resources Research Organization, Alexandria, Virginia, May 1977 (in progress).

Chapter 2

AN/PVS-5 NIGHT VISION GOGGLES: USER RATINGS OF CONVENIENCE, EFFECTIVENESS, AND COMFORT

Introduction

Human factors problems related to use of the AN/PVS-5 Night Vision Goggles (NVG) have been mentioned only in a general way in several reports, as such alleged difficulties were not central issues in these investigations. Therefore, as a first step, it seemed desirable to determine more systematically the variety and frequency of problems with the NVG. Accordingly, a questionnaire was developed and administered to personnel upon their return from operations involving extended NVG use. Several topics were covered on the questionnaire, including:

- (a) the facility with which goggles could be positioned and adjusted prior to use,
- (b) the ease of performing a number of specific flying tasks with the goggles versus the naked eye,
- (c) the nature of discomfort or fatigue experienced while using the goggles,
- (d) judgments of whether or not this discomfort or fatigue would degrade aviators' performance.

The specific set of questions relating to each topic was derived through conferences with aviators and other personnel of the 6th Cavalry Brigade (Air Combat) [6th ACCB]. The finished questionnaire was reviewed locally, revised, and pretested with four aviators. A copy of the final questionnaire is included as Appendix A. One long-range purpose of the questionnaire was to aid in the selection of visual performance tests which would reflect problems related to aircraft operation after extended goggle use.

The questionnaire was distributed to members of the 6th ACCB by HumRRO personnel during June and August 1977. Two groups of subjects received the questionnaire--aviators and motorcycle scouts. Because of some important differences in the pattern of responses between aviators and motorcycle scouts, the results for these groups were analyzed separately, and will be discussed separately and compared. The findings are summarized below.

Participants

Participants in the questionnaire study were personnel assigned to the 6th ACCB, Fort Hood, Texas. All participants completed the questionnaire upon returning from maneuvers requiring the wearing of NVG. The total number of participants was 27: 21 rotary wing aircraft aviators, and 6 motorcycle scouts.

Personal data.

(a) Aviators. Five respondents were commissioned officers, all of whom were captains. The remaining 16 were warrant officers: 2 WO1s, 12 CW2s, and 2 CW3s. Average age was 28, with 14 of the respondents aged 20 to 29, and 7 aged 30 to 39. Average time served in the military was 7.75 years; average career total hours of flight time was 1672 hours, with a range of 326 to 3400.

(b) Motorcycle Scouts. All motorcycle scouts were enlisted men: one E2, two E3s, one E4, and two E5s. Average age was 22, with one man under 20 and none over 30. Average time served in the military was 2.83 years.

Experience with AN/PVS-5 NVG.

(a) Aviators. Participants reported having flown from 1 to 100 hours with the NVG during their careers, the average total being 28.98. The length of the flight from which the aviators had returned just prior to completing the questionnaire averaged 2.18 hours. During this flight, the NVG were worn an average of 1.61 hours.

(b) Motorcycle Scouts. Scouts reported between 12 and 15 total riding hours while wearing the NVG, with an average of 13.2 hours. On the mission immediately preceding completion of the questionnaire, the NVG were worn for an average of 1.5 hours.

Task Vehicle and Equipment

(a) Aviators. Each respondent had just returned from a helicopter mission. Twelve aviators had flown in an AH-1G, four in an OH58, three in a UH-1H, and two gave no indication of the aircraft type. Aviators wore the NVG in conjunction with the SPH-4 helmet, which weighs 3.4 pounds.

(b) Motorcycle Scouts. All motorcycle scouts had ridden TS-185 motorcycles. The scouts wore the NVG with a commercial motorcycle crash helmet, Bell Helmets, Inc., Model R-T, weighing 2.13 pounds. These helmets are purchased from a local distributor and covered with a camouflage helmet cover for Army use.

A picture of each helmet alone, as well as being modeled with the NVG, appears in Figures 2-1 through 2-4.



Figure 2-1. The SPH-4 aviator helmet.



Figure 2-2. AN/PVS-5 night vision goggles worn with the SPH-4 aviator helmet.



Figure 2-3. The Model R-T motorcycle crash helmet.



Figure 2-4. AN/PVS-5 night vision goggles worn with the Model R-T motorcycle crash helmet.

User Opinions

Concerning ease of positioning and adjustment. Respondents were asked to rate, in terms of their ease of accomplishment, several tasks related to adjusting the goggles for wear. Twenty aviators and all six motorcycle scout participants indicated their ratings by checking one of four choices for each of the five tasks. The complete set of ratings given by each group is shown in Table 2-1.

Mann-Whitney U tests were conducted on overall ratings and ratings for each task to compare the responses of the aviators with those of the motorcycle scouts. This was done by assigning numerical scores to each response as follows: Very Easy - 1; Easy - 2; Difficult - 3; and Very Difficult - 4. The nonparametric Mann-Whitney U test was selected because its use avoids the assumption of normally distributed data of equal variance around the means being compared, while retaining a great deal of statistical power.¹

The tasks surveyed included placing the goggles on the head by attaching them to the helmet, adjusting goggles and helmet for comfortable wear, adjusting interpupillary distance, diopter adjustment, and focusing.

Table 2-1. Ease of Accomplishment of NVG Positioning and Adjustment Tasks for Aviators and Motorcycle Scouts

	<u>Very Easy</u>	<u>Easy</u>	<u>Diffi- cult</u>	<u>Very Difficult</u>
a. Attaching goggle to helmet	4 (2)	1 (14)	1 (4)	0 (0)
b. Adjusting for comfort	4 (1)	1 (10)	1 (6)	0 (3)
c. Adjusting interpupillary distance	5 (4)	1 (14)	0 (1)	0 (1)
d. Diopter adjustment	4 (6)	1 (13)	1 (1)	0 (0)
e. Focusing	4 (8)	1 (11)	1 (1)	0 (0)

No parentheses: Motorcycle Scouts

Parentheses: Aviators

Overall, the motorcycle scouts found the goggles easier to use, $U(6, 20) = 24, p < .05$. The modal response to all task ratings by the

¹S. Siegel. *Nonparametric Statistics for the Behavioral Sciences*. New York: McGraw-Hill, 1956.

motorcycle group was "Very Easy," while that by the aviators was "Easy." This pattern was present for each of the five individual items as well. However, for the individual tasks, the only statistically significant difference between the responses of the groups concerned adjusting goggles and helmet for comfortable wear, $U(6, 20) = 22, p < .02$, and adjusting interpupillary distance, $U(6, 20) = 20, p < .02$.

The reported differences in the rated ease of adjustment of the helmet/goggle configuration between the two groups can better be understood by considering the differences in how goggles are mounted to the aviator helmet and to the motorcycle crash helmet. The aviators attach the NVG only to the helmet, fastening the lower straps to snaps and the upper straps to velcro. The motorcycle scouts attach the lower straps to snaps on the helmet, but the upper support for the goggles is to the head via a headstrap. This latter configuration allows for relatively independent adjustment of goggles and helmet, and should thus lead to greater comfort. Physical differences between the SPH-4 and Model R-T helmets do not suggest why adjusting interpupillary distance is easier for the motorcycle scouts, and no explanation is readily apparent for this result.

Concerning task-related effectiveness. Each aviator respondent was asked to indicate which of approximately 40 maneuvers or tasks had been performed during the immediately preceding flight. For those tasks which were performed, the aviator was then asked to judge whether the difficulty of performing them with the NVG was greater than, less than, or about the same as with the naked eye. This section was inapplicable to riding a motorcycle, and hence was not completed by the motorcycle scouts.

A summary of the results appears in Table 2-2. It can be seen that the NVG were preferred to the naked eye for Nap-of-Earth (NOE) and terrain flight operations, confined area operations, and the complex maneuvers described toward the end of the table. As the ambient night illumination appears markedly increased while viewing through the NVG, these results are readily understandable. For tasks which require high visual acuity and good depth perception, such as hover maneuvers, slope operations, and take-off and approach tasks, the goggles were less favored over the naked eye. The well-documented restriction on visual resolution² and depth perception³ related to viewing through the NVG provide a simple explanation for these latter findings. Nevertheless, the respondents showed a definite preference for the naked eye over the NVG only for slope operations.

² R. W. Wiley and F. F. Holly. *Vision With the AN/PVS-5 Night Vision Goggles*, ARL-76-DA 1498, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, April 1976.

³ R. W. Wiley, D. D. Glick, C. T. Bucha, and C. K. Park. *Depth Perception With the AN/PVS-5 Night Vision Goggle*, USAARL Report 76-25, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, July 1976.

Table 2-2. Aviator Judgments of Difficulty of Performing Helicopter Maneuvers and Tasks with AN/PVS-5 NVG Compared with the Naked Eye

<u>Maneuver/Task</u>	<u>Difficulty of Performance with AN/PVS-5 NVG Compared with the Naked Eye</u>		
	<u>NVG Less Difficult</u>	<u>About the Same</u>	<u>NVG More Difficult</u>
Take-off to hover	8	6	7
Landing from hover	8	5	8
Normal take-off	9	10	2
Normal approach	8	8	4
Steep take-off	4	7	2
Steep approach	3	6	4
Slope operations	3	5	8
Confined area operations	12	1	3
Pinnacle operations	1	0	1
Flight above 200' above ground level	5	5	4
Low level flight	12	5	1
Contour flight	14	3	2
NOE flight	13	0	5
NOE quick stop	10	2	2
NOE down-wind take-off	9	4	1
NOE down-wind landing	9	4	0
Inadvertant inst meteo-logical cond	2	1	0
Instrument take-off	3	2	0
Inst app (non-prec)	3	0	0
Sling load operations	1	0	0
Hovering auto 5'	3	1	0
Hovering auto 15'	1	0	0
Low level auto 50'/50k	2	0	0
Low level auto 50'/80-90k	2	1	1
Low level auto 50'/130k	2	0	0
Standard auto	2	0	0
Stan auto with turn	1	0	0
Anti-torque failure	1	0	0
Hydraulic failure	1	0	1
Forced landing	3	0	0
Route recon	4	0	0
Zone recon	6	0	0
Area security	6	0	0
Screen	4	0	0
Guard	4	0	0
Covering Force	5	0	0
Economy of force	3	0	0
Raid	3	0	0
Radiological survey	0	0	0
Rappelling	0	0	0
Insert/extract ground scout	0	0	0
Mine dispensing	0	0	0

Concerning discomfort and fatigue.

Sources of discomfort.

(a) Aviators. Of the 21 aviators, 20 reported experiencing physical discomfort while wearing the NVG. Nine specific possible discomfort and fatigue symptoms were listed, as shown in Table 2-3. Respondents checked the appropriate symptoms with frequencies as indicated in the Table (column a). In addition, three aviators each described one experience not on the original checklist. These were: (1) pain and pressure on the forehead at the hairline; (2) pressure on the back of the head; and (3) continuous difficulty with the goggles slipping down on the face. As shown in the table, facial discomfort in the form of

Table 2-3. Frequencies of Reports of Specific Symptoms of Discomfort for Aviators (a) and Motorcycle Scouts (b)

<u>Symptom</u>	<u>Frequency</u>	
	(a)	(b)
Pressure on bridge of nose	9	5
Pressure on cheek bones	11	3
Fatigue of neck muscles	12	3
Fatigue of back muscles	4	1
Headaches	10	2
Disorientation	2	5
Vertigo	0	1
Dizziness	0	0
Eyestrain	8	4

pressure on the nose and cheek bones, fatigue on neck muscles, headaches, and eyestrain were frequently cited, while there was no report of vertigo or dizziness. Only a few aviators reported back muscle fatigue or disorientation. All in all, however, physical discomfort and muscular fatigue were widely acknowledged to accompany NVG use.

(b) Motorcycle Scouts. Since the helmet/goggle configuration is more favorable for motorcycle scouts than for aviators (due to the lighter and higher-browed helmets used by the former, as well as the favored strap attachments used by this group), one might expect the motorcycle scouts to report less difficulty with discomfort and fatigue. However, of the six respondents, five reported having such problems. The responses of the motorcycle scouts are shown in Table 2-2 (column b). Once again, facial discomfort, neck fatigue, headaches, and eyestrain were widely reported. In addition, all motorcycle scouts who experienced difficulty indicated that disorientation was a problem, and one reported experiencing vertigo. Since driving a motorcycle involves a number of quick motor responses to objects at close range, perhaps

these latter two symptoms arose from situations which are not as consistently involved in piloting an aircraft. No motorcycle scout reported experiencing dizziness, nor was there any description of a complaint not included in the original checklist.

Time course of discomfort. All respondents who reported discomfort were asked to give an estimate of the number of minutes they had worn the NVG before the discomfort became apparent. The resulting means, standard deviations, and ranges for both groups are presented in Table 2-4. The difference between mean time to discomfort for aviators and that for motorcycle scouts was analyzed with the Mann-Whitney U test. This difference was not significant, $U(3, 20) = 27, p > .10$. Note that of the five motorcycle scouts reporting discomfort, only three indicated the duration of goggle wear before discomfort was noticed.

Table 2-4. Minutes of AN/PVS-5 Goggle Wear Before Discomfort Became Apparent

<u>Group</u>	<u>Mean</u>	<u>SD</u>	<u>Range</u>
Aviators (N = 20)	42.50	34.05	110.0
Motorcycle Scouts (N = 3)	29.17	8.78	17.5

The respondents reporting discomfort were also asked to estimate how long they felt they could wear the NVG before discomfort would degrade performance. The data for the responses of each group appear in Table 2-5. The difference between mean estimates of time to performance degradation was not statistically significant, $U(3, 20) = 27, p > .10$.

Table 2-5. Estimated Number of Minutes Goggles Could be Worn Before Performance Would be Degraded

<u>Group</u>	<u>Mean</u>	<u>SD</u>	<u>Range</u>
Aviators (N = 20)	95.5	40.16	150
Motorcycle Scouts (N = 3)	100.0	34.64	60

The overall responses indicate that discomfort sets in at an average of 40 minutes after the NVG are positioned. The users also estimated that after approximately 1 hour and 40 minutes of NVG wear the discomfort would become so pronounced that performance would be degraded.

Concerning other related problems. Respondents were also asked to describe any other problems they might have experienced with the NVG which had not been expressed in the questionnaire.

(a) Aviators. The aviators had a number of specific comments. There were three remarks regarding a tendency of the outside lenses of the goggles to fog when the Environmental Control Unit was used to cool the helicopter cockpit. Two comments each were made in relation to the problems which have been investigated in previous studies: poor visual acuity,⁴ poor depth perception,⁵ and inability to read maps due to lack of color vision.⁶ One aviator complained of lack of peripheral vision while using the NVG, which is due to the field of view through the goggles being limited to 40 degrees. Another aviator mentioned eye fatigue which had in the past persisted for at least 24 hours after the NVG were removed.

(b) Motorcycle Scouts. Two of the motorcycle scouts mentioned a problem with poor depth perception.

Summary and Conclusions of Aviator/Motorcycle Scout Comparisons

The motorcycle scouts, who wear a light helmet which leaves the lower forehead uncovered, rated positioning and adjusting the NVG for use as easier than did the aviators wearing the heavier, full-browed SPH-4 helmet. Both groups found the NVG about equally uncomfortable. Therefore, attempts at alleviating the discomfort should take into account characteristics of the helmet/goggle mating which would apply to both helmets.

The visual problems encountered in viewing through the NVG which were noted by both groups are due primarily to the optical characteristics of the goggles' light intensification system. Any improvements here must await further technological research.

⁴ Wiley and Holly, *op. cit.*

⁵ Wiley, et al., *op. cit.*

⁶ D. D. Glick and R. W. Wiley. *A Visual Comparison of Standard and Experimental Maps Using the AN/PVS-5 Night Vision Goggle*, USAARL Letter Report-75-26-7-6, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, March 1975.

Effects of Experience with the NVG

The aviator respondents reported a wide range of career experience with the NVG. One respondent indicated a total goggle use of only one hour, while several reported having used them for approximately 100 hours. Ten hours of flying experience with the NVG is required before an aviator is qualified to fly while wearing the goggles outside the presence of an Instructor Pilot (IP). In verbal reports, 6th ACCB IPs related that aviators are at first very apprehensive about flying with the NVG, but that after gaining enough experience to qualify with the goggles, their attitude becomes much more positive. Perhaps such confidence in both the NVG's usefulness and their own ability to perform while wearing the goggles would be reflected in the more experienced aviators' judgments of NVG convenience, effectiveness, and comfort.

To investigate the effects of experience on aviators' ratings of the NVG, the 21 questionnaires were divided into two groups, one of aviators who had qualified, and another of those who had not, and re-analyzed. Responses of the groups were compared using the Mann-Whitney U test. Fourteen respondents had qualified with the goggles, while seven had not. The personal characteristics of the members of the two groups are given in Table 2-6. Besides differing in the amount of flying experience with the NVG, members of the groups also differed in number of years of military service, $U(7, 14) = 18, p < .05$, and total hours of flying experience, $U(7, 14) = 7, p < .002$. The groups did not differ on any other characteristic (all $ps > .10$).

On ratings of convenience. Differences in patterns of responses on convenience measures between the two groups were analyzed by assigning numerical scores to the responses: Very Easy - 1; Easy - 2; Difficult - 3; and Very Difficult - 4. The distribution of responses to each question for the groups is shown in Table 2-7. Statistical comparisons were made as one-tail Mann-Whitney U tests, since aviators who had qualified with the NVG were expected to be more positive in their responses than those who had not qualified.

The overall modal response to the questions was "Easy" for both groups. However, the groups did differ in their overall judgments of convenience of adjustment, $U(7, 14) = 8, p < .001$, with the qualified aviators rating the NVG more favorably. Regarding the convenience of particular adjustments, the qualified group seemed to find the goggles easier to attach to the helmet, $U(7, 14) = 17, p < .01$; easier to adjust for comfortable wearing, $U(7, 14) = 12, p < .01$; and easier to adjust regarding interpupillary distance, $U(7, 14) = 23, p < .05$. There was no significant difference between the groups for either diopter adjustment or focusing, $U(7, 14) = 28$, and $U(7, 14) = 40$, respectively. As adjustment tasks should become somewhat easier with practice, it is not surprising that the aviators with more experience with the NVG found some of the adjustments easier to perform than did those with less experience.

Table 2-6. Characteristics of Groups of Aviator Respondents
Who Had and Had Not Qualified with the NVG

<u>Characteristic</u>	<u>Qualified</u>	<u>Not Qualified</u>
Number	14	7
Mean Age in Years	28.71	27.83
Age Range		
Minimum	23.00	26.00
Maximum	34.00	32.00
Mean Years of Service	8.66	5.93
Mean Career Hours Flying Time	2110.00	796.00
Mean Hours Duration of Current Flight	2.26	2.04
Mean Hours NVG Worn on Current Flight	1.65	1.53
Mean Career Hours Flown Wearing NVG	40.71	4.21
Range Career Hours Flown Wearing NVG		
Minimum	10.00	1.00
Maximum	100.00	8.50

Table 2-7. Accomplishment of NVG Positioning and Adjustment Tasks for Aviators Who Had and Had Not Qualified with the NVG

	<u>Very Easy</u>	<u>Easy</u>	<u>Diffi- cult</u>	<u>Very Difficult</u>
a. Attaching goggles to helmet	2 (0)	11 (3)	4 (0)	0 (0)
b. Adjusting for comfort	2 (0)	8 (1)	3 (3)	0 (3)
c. Adjusting interpupillary distance	4 (0)	9 (5)	0 (1)	0 (1)
d. Diopter adjustment	6 (0)	6 (7)	1 (0)	0 (0)
e. Focusing	6 (2)	6 (5)	1 (0)	0 (0)

No parentheses: Qualified
Parentheses: Not qualified

On ratings of effectiveness. The respondents with less NVG experience were also expected to find the goggles less helpful in performing flying tasks and maneuvers than the more experienced group. To allow a statistical comparison of the responses of the two groups, a response that the task was less difficult with the NVG than with the naked eye was assigned a score of -1; a response that the task was more difficult with the NVG was given a score of +1; and a response judging the two to be about equal was assigned a score of 0. For each respondent, an average was derived by totaling the numerical scores assigned to each response and dividing by the total number of responses. As was anticipated, those less experienced with the NVG rated them less favorably, $U(7, 14) = 21, p < .025$. The responses of each group to this section of the questionnaire are shown in Table 2-8. Response frequencies reveal that the experienced group usually found the specified tasks to be performed more easily with the NVG, while the less experienced tended to prefer the naked eye, even in darkness.

One possibly confounding factor in the foregoing analysis is an uneven distribution of the types of tasks and maneuvers performed by the two groups. Further analysis showed that the group who had qualified performed a larger variety of tasks during the criterion flight than did the other group, $U(7, 14) = 24, p < .05$, with an average of 17.07 items for the former and 11.57 for the latter. It is thus possible that those additional tasks and maneuvers in which the experienced group participated were the ones for which the NVG would be the most helpful. If so, the difference in ratings would reflect more about differences in the types of activities undertaken by each group than about the effectiveness of the NVG. An analysis was therefore conducted considering only those 11 items that were included in the activities of over half the members of each group. These are indicated with an asterisk in Table 2-8. Once again, the responses of the groups differed significantly, $U(7, 14) = 21, p < .025$, with the less experienced reporting less satisfaction with the NVG. Training with the NVG therefore seems to have a positive effect on the extent to which aviators rate the goggles useful in performing most basic flying tasks.

On ratings of comfort. On the basis of trends detected in the data, aviators who were qualified with the NVG could be expected to report less discomfort while using the goggles than those who were not qualified. This might occur simply because the more experienced group had adapted to the discomfort, perhaps by devising ways of coping with the pressure and strain. A comparison of the responses of the two groups, as shown in Table 2-9, did not show a significant difference in the average number of adverse symptoms cited, $U(7, 14) = 31$. However, the less experienced group did report experiencing discomfort sooner after positioning the NVG than did the more experienced, $U(7, 13) = 21, p < .025$. Note that one aviator in the more experienced group reported no discomfort. A correlation computed over the responses of all 20 aviators between the number of hours of NVG experience and estimated number of minutes to discomfort was low and hence not statistically significant, $r = +.19, df 18, p > .10$, although this correlation was

Table 2-8. Judgments of Difficulty of Performing Helicopter Maneuvers and Tasks with AN/PVS-5 NVG Compared with the Naked Eye for Aviators Who Had and Had Not Qualified with the NVG

<u>Maneuver/Task</u>	<u>Difficulty of Performance with AN/PVS-5 NVG Compared with the Naked Eye</u>		
	<u>NVG Less Difficult</u>	<u>About the Same</u>	<u>NVG More Difficult</u>
*Take-off to hover	7 (1)	5 (1)	2 (5)
*Landing from hover	7 (1)	4 (1)	3 (5)
*Normal take-off	7 (2)	7 (3)	0 (2)
*Normal approach	6 (2)	6 (2)	1 (3)
*Steep take-off	3 (1)	4 (3)	1 (1)
*Steep approach	2 (1)	4 (2)	2 (2)
*Slope operations	2 (1)	3 (2)	6 (2)
Confined area ops	10 (2)	1 (0)	3 (1)
Pinnacle ops	1 (0)	0 (0)	1 (0)
*Flight above 200' above ground level	5 (0)	3 (2)	2 (2)
*Low level flight	12 (1)	3 (2)	0 (1)
*Contour flight	12 (2)	1 (2)	1 (1)
*NOE flight	12 (1)	0 (0)	2 (3)
NOE quick stop	9 (1)	1 (1)	1 (1)
NOE down-wind take-off	8 (1)	2 (2)	1 (0)
NOE down-wind landing	8 (1)	2 (2)	0 (0)
Inadvertant inst meteorological cord	1 (1)	1 (0)	0 (0)
Instrument take-off	2 (1)	1 (1)	0 (0)
Inst app (non-prec)	2 (1)	0 (0)	0 (0)
Sling load ops	1 (0)	0 (0)	0 (0)
Hovering auto 5'	2 (1)	1 (0)	0 (0)
Hovering auto 15'	1 (0)	0 (0)	0 (0)
Low level auto 50'/50k	2 (0)	0 (1)	0 (0)
Low level auto 50'/80-90k	2 (0)	1 (0)	1 (0)
Low level auto 50'/130k	2 (0)	0 (0)	0 (0)
Standard auto	2 (0)	0 (0)	0 (0)
Stan auto w/turn	1 (0)	0 (0)	0 (0)
Anti-torque failure	1 (0)	0 (0)	1 (0)
Forced landing	3 (2)	0 (0)	0 (0)
Route recon	4 (0)	0 (0)	0 (0)
Zone recon	5 (1)	0 (0)	0 (0)
Area security	5 (1)	0 (0)	0 (0)
Screen	3 (1)	0 (0)	0 (0)
Guard	3 (1)	0 (0)	0 (0)
Covering force	5 (0)	0 (0)	0 (0)
Economy of force	3 (0)	0 (0)	0 (0)
Raid	3 (0)	0 (0)	0 (0)
Radiological survey	0 (0)	0 (0)	0 (0)
Rappelling	0 (0)	0 (0)	0 (0)
Insert/extract ground scout	0 (0)	0 (0)	0 (0)
Mine dispensing	0 (0)	0 (0)	0 (0)

No parentheses: Qualified
Parentheses: Not Qualified

Table 2-9. Discomfort Estimates Given by Groups of Aviators
Who Had and Had Not Qualified with the NVG

<u>Index</u>	<u>Qualified</u>	<u>Not Qualified</u>
Mean Number of Symptoms Cited	2.57	3.29
Mean Number of Minutes to Discomfort	51.54	25.00
Range in Estimate of Minutes to Discomfort		
Minimum	15.00	5.00
Maximum	115.00	90.00
Mean Number of Minutes to Performance Degradation	113.08	61.43
Range in Estimates of Minutes to Performance Degradation		
Minimum	60.00	30.00
Maximum	180.00	120.00

much higher within the less experienced group, $r = +.91$, $df = 5$, $p < .005$ by a one-tail test. The two measures were not significantly correlated within the more experienced group, $r = -.24$, $df = 11$, $p > .10$.

The less experienced group gave a significantly lower estimate of the number of minutes the NVG could be worn before a performance decrement would occur than did the more experienced, $U(7, 13) = 12$, $p < .01$. The correlation between amount of NVG experience and estimated time to performance decrement was statistically significant, $r = +.47$, $df = 18$, $p < .025$. This correlation was higher if only the less experienced group is considered, $r = +.81$, $df = 5$, $p < .025$, while a significant correlation between those two measures did not exist for the more experienced group, $r = +.19$, $df = 11$, $p > .10$.

Discomfort and the eventuality of degraded performance were associated with NVG wear for aviators of both experience levels. Members of the qualified group wore the NVG for an average of almost one hour without reported discomfort, which is almost twice the average estimate by the group who were not qualified. On judgments of duration of wear before performance would suffer substantially, again the groups differed in approximately a 2:1 ratio. The estimate of the more experienced

averaged almost two hours, while the less experienced felt that about one hour on the average would be their limit. It is improbable that greatly increasing the hours of training with the NVG would raise the estimates of time to discomfort and performance decrement beyond those made by the most experienced pilots, since the magnitude of these estimates was unrelated to amount of experience with the goggles for the more experienced group.

Summary and Conclusions on the Effects of Experience with the NVG

It was apparent from the responses of the groups that experience in flying with the NVG strongly influenced the aviators' opinions of convenience, effectiveness, and comfort in relation to NVG use. Nevertheless, even the more experienced aviators reported some difficulty in positioning and adjusting the NVG for wear, felt that the naked eye was preferable to the NVG for some tasks and maneuvers, and found the NVG both uncomfortable to wear and eventually detrimental to their ability to perform flying tasks.

Regardless of the amount of personal experience with the NVG, it would seem that the large majority of aviators could benefit from a helmet/goggle configuration modified to alleviate the reported discomfort and inconvenience.

General Discussion

There are strong indications that much can be done to increase user satisfaction with the NVG. Were the SPH-4 aviator helmet modified to leave slightly more of the brow exposed, the NVG would probably be easier to adjust and more comfortable as well. Aviators have informally commented that form-fitted helmets provide much better support for the NVG than do the SPH-4s, as the form-fitted helmet allows more weight to be taken off the face without causing the helmet to slip forward. Such relief is usually effected by attaching the velcro higher on the helmet than usual. Aviators have also suggested other methods of providing additional support for the goggles, such as counterweighting the helmet on the back or adding extra straps.

Since flying experience with the goggles seems closely tied to users' attitudes toward the NVG, perhaps training procedures could be devised in methods of alleviating some of the problems with the goggles. Additional practice on positioning and adjusting the NVG might also be given. The poor depth perception which plagues users in some situations could be improved by teaching aviators to make more head movements, thus strengthening the very effective depth cue of motion parallax. Exercises to build up the neck muscles, and thereby prevent fatigue from that source, might be introduced.

Chapter 3

FATIGUE FROM AN/PVS-5 NVG AS REFLECTED IN PERFORMANCE TESTS

As indicated in the NVG user ratings reported in Chapter 2, eventual performance degradation during extended goggle wear was predicted by almost all aviators surveyed. Questions arise regarding which visuo-motor abilities used in operating rotary wing aircraft are most severely affected. The degree to which various abilities suffer is relevant to considerations of pilot safety and the effectiveness with which various missions can be accomplished.

Design of the Experiment

The extent of degradation of various abilities after lengthy goggle use must be determined by direct observation. Actual monitoring of the flight performance of aviators is extremely difficult. More accurate, quantitative measures also are preferable. Various human performance tests, administered to aviators before and after flights in which the NVG are extensively used, seem capable of providing the desired information. Accordingly, several such tests were selected and administered.

Test Selection

Human performance tests were selected from among those indicated in the literature as sensitive to fatigue. The specific tests chosen were those which measured abilities involved in piloting an aircraft. Five tests were selected and are described below. Variations of the first four tests have been used for pilot selection, and the last test measures overall visual efficiency. Background information concerning the effects of fatigue on the ability being tested appears after each description.

Double Broken Ring Acuity Test. This test requires the examinee to determine the position of a quadrant of a ring detached by gaps from the remainder of the ring. The detached quadrant can be at any one of eight positions relative to the center of the ring. The basic chart, printed by Baush & Lomb, #713599-101 ND, was viewed with the naked eye. Rings equal of size to those on the chart in the normal visual efficiency range of 20/45 to 20/125 were drawn on a larger chart which was viewed through the NVG. This chart is shown as Figure 3-1. Figures were arranged on the large chart to form 10 rows of nine figures per row. One figure from each visual efficiency range appeared on each row, with degree of difficulty increasing from left to right. The basic chart contained varying numbers of figures at each difficulty level, with all figures at a particular level grouped together in a row. Difficulty on the basic chart increased with successive rows toward the bottom. The

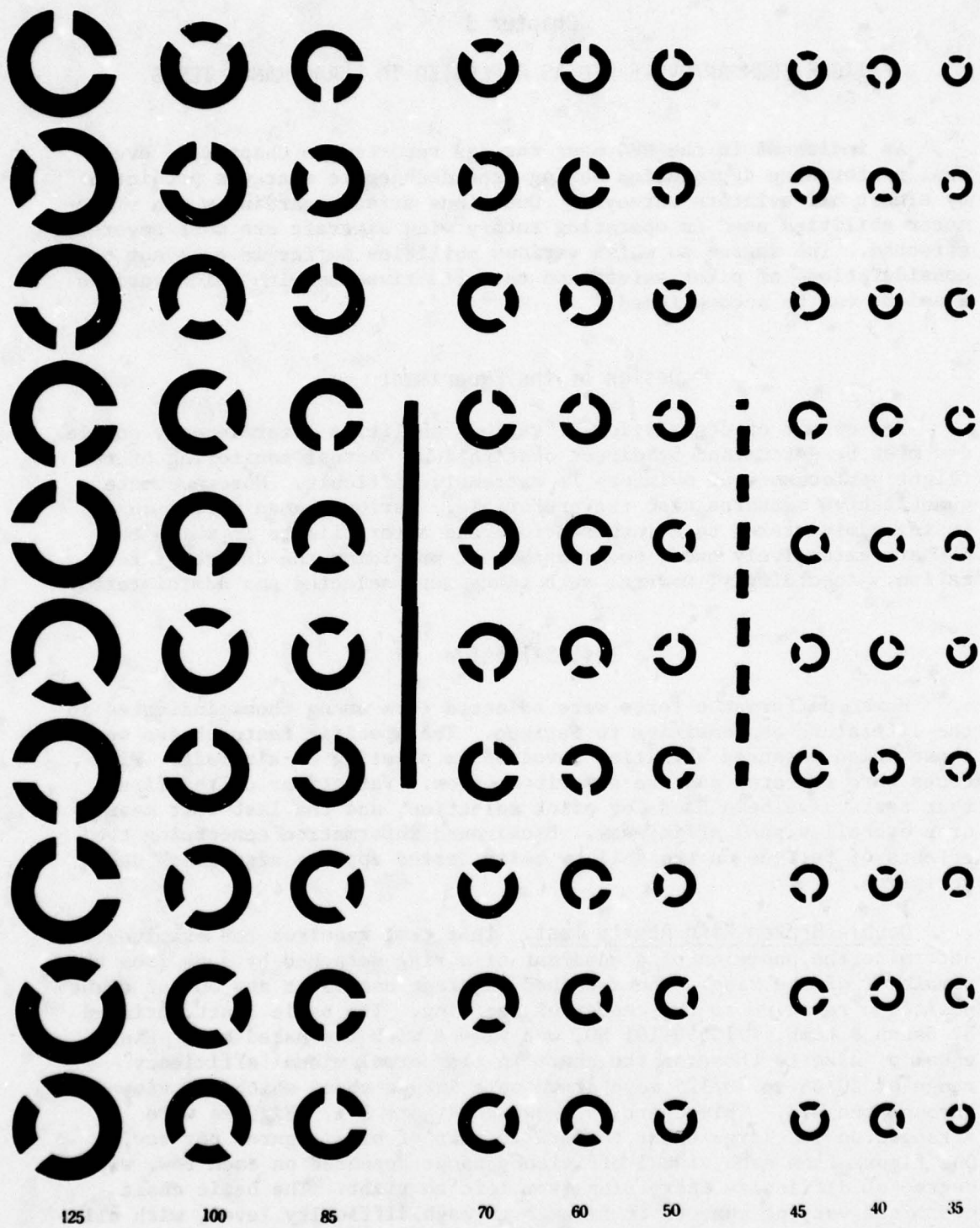


Figure 3-1. Double broken ring acuity chart viewed through the AN/PVS-5 night vision goggles

visual efficiency ratings of the figures viewed by participants appears in Table 3-2 (see Page 3-9). Examinees gave their responses aloud. Ambient room illumination was set at .02 foot-lamberts for viewing with the goggles, and 10 foot-lamberts for viewing with the naked eye.

As a fundamental assessment of the NVG as an optical device, un-fatigued subjects' levels of through-the-lens visual acuity were compared with those found elsewhere.¹ Fatigue from piloting an aircraft has been shown to affect acuity adversely, although to a relatively minor degree.² Therefore, some difference in acuity levels could be expected between participants in the two experimental conditions.

Howard-Dolman Depth Discrimination Test. A modified Howard-Dolman apparatus was used to measure relative depth discrimination. The apparatus usually consists of two vertical rods--a standard and a variable--which are viewed from a distance of six meters through a 236mm by 154mm window in the front of a box which houses the rods. The subject attempts to align the variable rod with the fixed comparison rod by pulling a rope to move the former closer or further away. The modification consisted of attaching both rods, each 12.5mm wide and separated by 140mm, to the alignment rope. Hence, when one rod moved toward the observer, the other simultaneously moved backward by the same distance. The apparatus was constructed by the Training and Audiovisual Support Center at Fort Hood. Each participant tested used both the NVG and the naked eye. Illumination was varied inside the apparatus from .02 foot-lamberts for observations with the NVG to 6 foot-lamberts for viewing with the naked eye. Ambient room illumination was .02 foot-lamberts in the former viewing situation, and 10 foot-lamberts in the latter. Each participant aligned the rods five times under each of the two viewing situations after making two practice alignments using the NVG and one using the naked eye.

Fatigue produced from operating a vehicle has been shown to degrade depth perception.^{3,4} Levels of accuracy for depth perception under both

¹R. W. Wiley and F. F. Holly. *Vision With the AN/PVS-5 Night Vision Goggles*, ARL-76-DA 1498, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, April 1976.

²S. Narasaki, J. Fukida, M. Kozadki, and N. Takimoto. On the Fatigue of Civil Air Transportation Crews Observed From Their Visual Functions, *Japanese Journal of Aerospace Medicine and Psychology*, 1969, 6, 35-41.

³B. F. Jones, R. H. Flinn, and E. C. Hammond. "Fatigue and Hours of Service of Interstate Truck Drivers," Public Health Bulletin No. 265, US Government Printing Office, Washington, D.C., 1941.

⁴M. J. Herbert and W. E. Jaynes. *Performance Decrement in Vehicle Driving*, USAMRL Report No. 597, US Army Medical Research Laboratory, Fort Knox, Kentucky, November 1963.

NVG and naked eye viewing conditions have been determined experimentally for unfatigued individuals,^{5,6} and provide a baseline with which to compare performance of both groups in the current experiment.

Pursuit Rotor Test of Eye-Hand Coordination. The participant in this test attempts to keep a stylus directly over a brightly-lit bar which moves at an irregular velocity around a triangular track. The rate of revolution was set at 30 per minute. Each trial was approximately 20 seconds in duration, with the trial onset and offset controlled by a switch held by the experimenter. The trial duration was timed by a decade counter, manufactured by Cramer Division, Giannini Controls Corporation. Time on target was measured and displayed to the nearest .01 second by an Industrial Timer Corporation timer, which was reset after each trial. The pursuit rotor apparatus was manufactured by Research Media, Inc. Ambient room illumination was 10 foot-lamberts. Each participant received five criterion trials while using the naked eye, preceded by two practice trials.

Eye-hand coordination has been shown to be adversely affected by fatigue induced through driving a vehicle.^{7,8} As such coordination is vital in many helicopter tasks and maneuvers, the degree to which fatigue impairs such abilities is of great importance.

Choice Reaction Time Card Sort. Decks used in this test contained 36 cards, each 90mm by 60mm and bearing a pattern composed of two lines. The lines, separated by 4mm, were either both long (20mm by 20mm), both short (13mm by 13mm), the right long and the left short, or the left long and the right short. Each of the four patterns appeared in the center of nine cards of the deck. Four standards--one bearing each pattern--were placed before the participant, who was then handed a shuffled deck with a blank card on top. The participant tossed the blank card on the table, and immediately sorted the deck, putting each card in its proper stack upon the standard. When the blank card touched the table, the experimenter started a stopwatch which was stopped when

⁵Wiley and Holly, *op. cit.*

⁶R. W. Wiley, D. D. Glick, C. T. Bucha, and C. K. Park. *Depth Perception with the AN/PVS-5 Night Vision Goggle*, USAARL Report 76-25, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, July 1976.

⁷A. H. Ryan and M. Warner. The Effect of Automobile Driving on the Reactions of the Drivers, *American Journal of Psychology*, 1936, 48, 408-421.

⁸Jones, Flinn, and Hammond, *op. cit.*

the last card of the deck was placed in its stack. Participants were instructed to sort as fast as possible without making errors; however, if an error was made, that card was to be left as it lay without being transferred to its proper stack. Five criterion sorts were preceded by four practice sorts, and number of errors committed as well as duration was noted for each sort. All sorts were performed with the participant standing and using the naked eye in a room illuminated to 10 foot-lamberts.

This test was designed to measure choice reaction time, which has been shown to suffer in the performance of individuals who were fatigued after driving a vehicle,⁹ as well as in that of others who had performed various tasks requiring vigilance.¹⁰

Critical Flicker Fusion (CFF) Test of Visual Efficiency. The CFF test requires the observer to indicate verbally the point at which an ever more rapidly flickering square-wave light first appears to shine constantly. A General Radio Type 1544 Strobotac generated the light (beam candella of 4×10^6 at 3800 flashes per minute). The stroboscope was placed inside a small box, and was observed through a hole covered by a neutral density filter. The flickering field subtended a visual angle of 2.05 degrees. Room illumination was set at 10 foot-lamberts, and all measurements were taken with participants using the naked eye. The method of limits was used, with each observer being given four practice trials (two ascending and two descending) followed by ten criterion trials. The direction of the trials was randomized.

CFF is not only a satisfactory overall measure of visual efficiency,¹¹ but is also sensitive to fatigue.^{12,13} The effects of fatigue usually lower CFF,^{14,15} although fatigue produced by steady-state exer-

⁹*Ibid.*

¹⁰E. G. Aiken. *Response Reversal and Fatigue*, USAMRL Report No. 289, US Army Medical Research Laboratory, Fort Knox, Kentucky, January 1957.

¹¹P. Rey. The Interpretation of Changes in Critical Fusion Frequency, in W. T. Singleton, et al. (eds.), *Measurement of Man at Work: An Appraisal of Physiological and Psychological Criteria in Man-Machine Systems*, pp 115-120, New York: Van Nostrand Reinhold Company, 1971.

¹²Ryan and Warner, *op. cit.*

¹³Jones, Flinn, and Hammond, *op. cit.*

¹⁴E. N. Simonson and N. Enzer. Measurements of Fusion Frequency of Flicker as a Test of Fatigue of the Central Nervous System; Observations on Laboratory Technicians and Office Workers, *Journal of Industrial Hygiene and Toxicology*, 1941, 23, 83-89.

¹⁵E. N. Simonson and J. Brozek. Flicker Fusion Frequency Background and Applications, *Physiological Reviews*, 1952, 32, 349-378.

tion increases CFF.^{16,17} Since the exertion necessary to counteract the weight of the NVG is fairly steady, CFF was expected to be higher for the fatigued than for the unfatigued participants.

Procedure

Subjects were obtained from the 6th ACCB at Fort Hood, Texas. All were aviators of rotary wing aircraft. The study was conducted using facilities furnished by the 6th ACCB in order to allow the shortest possible subject transportation time between deplaning and testing. The study was run from 3 October 1977 to 22 February 1978.

Two groups of aviators were given the battery of human performance tests. The first group, composed of 20 individuals, served to establish a baseline standard for unfatigued aviators before a flight. All members of this group were tested early in the day, and none had flown immediately prior to being tested. The second group, composed of 14 individuals, was used to determine the extent of decrements in abilities used in flying after extensive use of the NVG. Twenty aviators were requested for this group, but difficulties in scheduling, inclement weather, and deadlines allowed the participation of only 14. Each member of the second group had just completed a flight requiring lengthy use of the goggles prior to being tested. Two aviators were tested in the early morning hours following a nighttime flight, four were tested before midnight following early evening flights, and eight aviators were tested in the afternoon after daytime flights. Use of the NVG in the latter was made possible by attaching filters, each weighing approximately 1.5 ounces, to the front of each goggle lens.

For the most part, two subjects were in the experiment room performing the various tests at any given time. As soon as both subjects were present, they were seated at a table and briefed about the nature of the tests. All subjects were asked to do their very best on each test, and no information regarding expected performance trends was given. In fact, care was taken to avoid references to aviators in the postflight condition as "fatigued," since such references could introduce lowered performance expectations from these subjects. Participants were assured that the results of the tests would not become part of their personnel records.

¹⁶ E. N. Simonson, N. Enzer, and R. W. Benton. Influence of Muscular Work and Fatigue on the State of the Central Nervous System, *Journal of Laboratory and Clinical Medicine*, 1943, 28, 1555-1567.

¹⁷ Simonson and Brozek, *op. cit.*

Testing began with the distribution of a brief personal history form (see Appendix B). Following the completion of this, each participant was handed a set of the NVG, and was asked to adjust and focus the goggles after the lights were lowered. The Double Broken Ring Acuity Test and the Howard-Dolman Depth Discrimination Test were then administered, in alternating order for the subjects. While performing in these tests, participants held the NVG in place with their hand(s); no head-strap or additional means of support was provided. After these tests were completed, the lights were raised, and the NVG were put away. All five instruments were then administered to subjects, all of whom performed using the naked eye. The order of the tests varied in a Latin square sequence.

Before each test, instructions were read to the participant, and questions were answered as appropriate. A full set of instructions for each test appears in Appendix C, along with the answer sheet which was marked by the experimenter. The test battery took approximately 50 minutes to complete. After all tests were completed, the subject was thanked for his participation and excused.

Results

Description of the Sample

Data were collected on 34 individuals, 20 in the Baseline group and 14 in the Postflight group. All were male aviators from the 6th ACCB, Fort Hood, Texas. Except for one captain in the Baseline group, all subjects were warrant officers (7 WO1s, 8 CW2s, 3 CW3s and 1 CW4 in the Baseline group; and 1 WO1, 7 CW2s and 6 CW3s in the Postflight group). Other personal statistics appear in Table 3-1. Only one statistically significant difference in the quantifiable characteristics of the groups emerged. Total career hours of NVG use reported by the aviators were ranked in ascending order of magnitude. A comparison of the ranks between the groups by the Mann-Whitney U test yielded a significant difference, $U(14, 20) = 27, p < .002$. A nonparametric test was chosen

Table 3-1. Personal Statistics Reported by Members of the Baseline and Postflight Groups

<u>Index</u>	<u>Baseline Mean</u> (n = 20)	<u>Postflight Mean</u> (n = 14)
Age	29.25	30.50
Years of Military Service	9.83	10.50
Career Total Hours of Flight Time	1664.65	2298.21
Career Total Hours NVG Use	2.25	24.11

because of the variance of the reported use for the Postflight group was 80 times that of the Baseline group. As indicated by the test, the Postflight group reported much more career experience with the NVG than did the Baseline group. Aviators in the Postflight group had worn the NVG for an average of 1.96 hours on the flight which had immediately preceded testing, with duration of wear for individuals ranging from 1.0 to 4.0 hours.

Test Results

Double Broken Ring Acuity Test. Overall proportion correct in the NVG and naked eye viewing conditions were computed for each subject. The means for each group in each viewing condition are shown in Table 3-2, along with the results of statistical tests of differences between the groups. The difference in performance between the two groups was marginally significant in the NVG condition, while the groups did not differ in the naked eye condition. The probable explanation for the difference is thus not better acuity for the Postflight subjects, but rather that the Postflight group had more experience with the NVG, and therefore were better able to focus and otherwise adjust them to their eyes.

Computations of proportion correct for each subject at each difficulty level were made. The means of each group at each level are given in Table 3-2. The threshold (50%) levels of acuity are in the 20/60 to 20/70 range, and are in good agreement with those published elsewhere.¹⁸ Although with chance accuracy the mean proportion correct should have averaged around .125 (since the detached quadrant was always at one of eight positions, by guessing alone a subject would be correct on 1/8 of the attempts), several means were much lower since subjects consistently refused to attempt the task at the most difficult levels. Statistical analyses were conducted at those levels in which mean accuracy was between 15% and 90%. The difference between the groups at several levels approaches statistical significance. A possible explanation has been offered for the marginally significant differences in the NVG viewing condition. No explanation is immediately obvious for the one marginal difference in the naked eye viewing condition, although an apparent difference of this magnitude would be expected with random sampling in almost 10% of the cases when there were no actual differences between the groups.

Correlation coefficients were computed for each group on overall performance of each subject between NVG and naked eye conditions. Acuity in the two viewing conditions might be expected to be positively related. That is, for any particular subject, a given level of performance in one condition would be expected in the other. This consistency

¹⁸ Wiley and Holly, *op. cit.*

Table 3-2. Proportion Correct on the Double Broken Ring Acuity Test
at Each Difficulty Level for the Baseline and Postflight Groups

Difficulty Level	Proportion Correct		t ($df = 32$)
	Baseline	Postflight	
NVG Viewing Overall	.372	.487	1.78*
20/125	.955	.950	-----
20/100	.820	.943	1.29
20/85	.735	.929	1.71*
20/70	.490	.600	.70
20/60	.245	.486	1.71*
20/50	.050	.214	1.79
20/45	.050	.100	-----
20/40	.000	.086	-----
20/35	.000	.071	-----
Naked Eye Viewing Overall	.675	.721	.55
20/30	1.000	1.000	-----
20/25	.963	.964	-----
20/20	.805	.900	.87
20/17.5	.710	.929	1.72*
20/15	.600	.743	.97
20/12.5	.400	.381	.12
20/10	.242	.131	1.44

*.05 < p < .10

was evident in the Baseline group ($r = +.57$, $df = 18$, $p < .01$), but not in the Postflight group ($r = +.08$, $df = 12$, $p > .10$). The statistically significant correlation between NVG and naked eye performance in the Baseline group is difficult to explain, since this group seemed unable to focus the goggles properly. Reasons for the difference in consistency in the groups are also unclear, although the explanation could conceivably be related to fatigue of the Postflight subjects.

Howard-Dolman Depth Discrimination Test. The linear displacement of the rods was measured to the nearest millimeter on each trial. The standard deviation of these distances over the five test trials in each viewing condition was considered as the subject's linear depth discrimination threshold for that condition. This procedure, discussed by Hirsch and Weymouth,¹⁹ permits the exclusion of constant error in the computation of a sensitivity index. Table 3-3 gives the average linear threshold of each group in each viewing condition. Thresholds in the naked eye condition are near the more sensitive end of the range found in other studies,²⁰ and means for the NVG condition are likewise slightly lower than those found elsewhere.²¹ Angular disparity thresholds in seconds of arc, also shown in Table 3-3, are given for comparison with those found in other investigations. These were computed using the following equation, also from Hirsch and Weymouth:²²

$$A = \frac{I(D)}{O^2} \times 206,280$$

where

A = angular threshold in seconds of arc
I = interpupillary distance
D = linear displacement of the rods
O = observation distance

Once again, these thresholds are consistent with those of more sensitive individuals viewing with the naked eye found elsewhere.²³ Angular

¹⁹M. H. Hirsch and F. W. Weymouth. Distance Discrimination. I. Theoretical Considerations, *Archives of Ophthalmology*, 1948, 39, 210-223.

²⁰H. J. Howard. A Test for the Judgment of Distance, *American Journal of Ophthalmology*, 1919, 2, 656-675.

²¹Wiley and Holly, *op. cit.*

²²Hirsch and Weymouth, *op. cit.*

²³L. L. Sloan and A. Altman. Factors Involved in Several Tests of Binocular Depth Perception, *Archives of Ophthalmology*, 1954, 52, 524-544.

thresholds in the NVG condition are also in reasonable agreement with other findings.²⁴

Table 3-3. Mean Linear and Angular Depth Thresholds in the NVG and Naked Eye Viewing Conditions for the Baseline and Postflight Groups

	Mean Linear Threshold (Centimeters)	Mean Angular Threshold (Seconds of Arc)
NVG Viewing		
Baseline	3.231	14.928
Postflight	3.026	14.093
Naked Eye Viewing		
Baseline	.846	3.773
Postflight	.907	5.000

Linear thresholds in the naked eye viewing condition were significantly lower than in the NVG condition for both the Baseline group ($t = 4.89$, $df = 19$, $p < .001$) and the Postflight group ($t = 10.11$, $df = 13$, $p < .001$). Angular thresholds were likewise lower with naked eye viewing for the Baseline and Postflight groups ($t = 7.22$, $df = 19$, $p < .001$; and $t = 5.66$, $df = 13$, $p < .001$, respectively). However, there was no significant difference between the groups in the naked eye condition in either linear threshold ($t = 1.38$, $df = 32$, $p > .10$) nor angular threshold ($t = 1.38$, $df = 32$, $p > .10$). The lack of between group difference was also apparent in the NVG condition ($t = .28$, $df = 32$, $p > .10$; and $t = .34$, $df = 32$, $p > .10$).

Pursuit Rotor Test of Eye-Hand Coordination. As trial durations were timed manually by the experimenter rather than by automatic means, mean trial duration for the Baseline group was compared with that for the Postflight group. The difference was not statistically significant; nor were the differences in trial durations between trials nor the interaction of trial durations with groups significant (all F s < 1.0). The means for these comparisons are given in Table 3-4.

Percent of time on target for each trial was computed for each subject. These trial means, as well as the overall mean for each group, appear in Table 3-5. The difference in mean overall performance of the groups was statistically significant ($F = 4.33$, $df = 1, 32$, $p < .05$).

²⁴Wiley and Holly, *op. cit.*

Table 3-4. Mean Hand-kept Durations for Each Trial within Each Group for the Pursuit Rotor Test of Eye-Hand Coordination

<u>Group</u>	<u>Trial</u>					<u>Overall</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
Baseline	20.003	20.015	20.065	20.045	20.035	20.033
Postflight	20.021	19.982	20.029	20.004	20.000	20.007

Table 3-5. Mean Percentage of Time on Target for Each Test Trial Within Each Group for the Pursuit Rotor Test of Eye-Hand Coordination

<u>Group</u>	<u>Trial</u>					<u>Overall</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
Baseline	80.614	82.870	84.289	83.164	84.283	83.044
Postflight	72.322	73.076	74.952	77.476	81.286	75.822
Average	76.468	77.973	79.621	80.320	82.785	79.433

However, comparisons of performance levels over several trials are often made using median rather than mean performance scores, since one anomalous trial has a large effect on the mean but leaves the median relationship undisturbed. However, the difference between the average median percent time on target of the Baseline group (83.64%) was likewise greater than that of the Postflight group (72.57%) ($t = 2.21$, $df = 32$, $p < .05$). The improvement in performance over trials was reflected in a significant difference between trials ($F = 11.32$, $df = 4, 128$, $p < .001$). Performance tended to improve faster over trials in the Postflight group than in the Baseline group, resulting in a highly significant interaction of trials with groups ($F = 52.89$, $df = 4, 128$, $p < .001$). Note that mean percent time on target on the last test trial for the Postflight group approached that for the Baseline group, and was indeed greater than the means for the Baseline group on the first test trial. This result may indicate that Postflight subjects required more practice to reach a given level of performance than did Baseline subjects. This hypothesis receives support from trends observed in the practice trials which were not included in the above analyses. The significant 10.85% superiority in mean percent time on target on the first practice trial of the Baseline group (64.07%) over the Postflight group (53.22%) was slightly larger than the significant 9.57% difference

on the second practice trial (76.02% vs 66.45%; $t_s = 1.89$ and 1.98 , respectively, $dfs = 32$, both $ps < .05$ by one-tail tests). Thus, subjects in the Postflight group performed more poorly when first attempting the unfamiliar eye-hand coordination task than did subjects in the Baseline group. The steady decrease with practice in differences between the groups leaves open the possibility that for highly practiced tasks the groups would not differ.

Choice Reaction Time Card Sort. Both duration and number of errors were recorded for each sort. The mean duration for each test sort as well as the overall mean of each group is shown in Table 3-6. The difference between the groups' mean overall performance was not statistically significant ($F < 1.0$); however, the median performance levels over trials are most often considered for purposes of statistical comparison. The difference between the average median sort duration of the Baseline group (32.273 sec) was not significantly different from that of the Postflight group (33.614 sec) ($t = .68$, $df = 32$, $p > .10$). There was no significant difference between sorts ($F = 1.64$, $df = 4, 128$, $p > .10$), although a difference in sorts between the groups was apparent in a significant groups by sorts interaction ($F = 3.96$, $df = 4, 128$, $p < .05$). The largest difference between the groups is on the first test sort, possibly indicating that Postflight subjects required more practice to reach their optimal performance level than did Baseline subjects. However, an analysis of the four practice sorts which preceded the test sorts revealed no significant differences between the groups nor trends in performance which would explain the interaction found in the test sorts. A post-hoc Neuman-Keuls analysis was conducted to determine whether differences between groups on any particular sort made a statistically significant contribution to the interaction. The results were negative. No firm explanation for the interaction is apparent; therefore, it is tempting to conclude that the effect is spurious.

Table 3-6. Mean Duration in Seconds for Each Test Sort within Each Group for the Choice Reaction Time Card Sort

<u>Group</u>	<u>Trial</u>					<u>Overall</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
Baseline	33.330	32.685	32.395	31.750	32.915	32.615
Postflight	36.000	32.464	33.686	33.886	32.914	33.790
Average	34.665	32.575	33.041	32.818	32.915	33.203

The relationship between the number of errors committed (an error was scored when a card was sorted into the wrong stack) and sorting time was explored. Seventy percent of subjects in the Baseline group and 64% of those in the Postflight group committed one or more errors during

the test sort series. Each subject was instructed before the practice sorts to become more cautious after an error was made in order to avoid additional errors. No admonitions regarding errors were made during the test sort series, however. Median sorting times were ranked in each experimental group. The data of errorless performers were separated from the data of those who had committed errors, and Mann-Whitney U tests were used to compare the ranks. In the Baseline group, subjects who showed errors had longer sorting times, $U(6, 14) = 19, p < .05$ by a one-tail test, indicating that after committing an error subjects in this group sorted more slowly. This pattern was not evident for the Postflight group, as no significant relationship existed between errors and sorting times, $U(5, 9) = 23, p > .10$. It seems therefore that Postflight subjects had forgotten the initial instructions, or were unwilling or unable to perform in accordance with them.

Critical Flicker Fusion (CFF) Test of Visual Efficiency. Mean CFF thresholds in Hz for ascending and descending presentations were computed for each subject. No statistically significant differences in these presentation modes existed for either the Baseline group ($t = .44, df = 19, p > .10$) or the Postflight group ($t = 1.58, df = 13, p > .10$). An overall mean CFF threshold was thus computed for each subject. The difference between the average threshold of the Baseline group (31.73 Hz) and that of the Postflight group (44.13 Hz) was highly significant ($t = 6.29, df = 32, p < .001$). Thus the physical exertion experienced in the preceding flight with the NVG by the Postflight subjects was reflected in a lowering of their CFF threshold (i.e., fusion occurred at a higher frequency).

Performance and Duration of NVG Use

The size of the sample who had worn the NVG immediately prior to being tested was small ($N = 14$), and the range of use durations for this group was restricted (1.0 to 4.0 hours). Nevertheless, correlations between use duration and performance levels on the various tests were examined in an effort to gain more information from the data collected. Performance measures from each subject included in the computations from each test were the following:

- Double Broken Ring Acuity Test - overall proportion correct for each viewing condition.
- Howard-Dolman Depth Discrimination - linear depth threshold for each viewing condition.
- Pursuit Rotor Test of Eye-Hand Coordination - median percent of total time on target.

- Choice Reaction Time Card Sort - median sorting time.
- Critical Flicker Fusion (CFF) Test of Visual Efficiency - mean threshold.

Correlation coefficients and related t values appear in Table 3-7.

Table 3-7. Correlations Between Duration of NVG Use and Performance Levels for the Postflight Group

<u>Test</u>	r	t ($df = 12$)
Double Broken Ring Acuity		
NVG Viewing	-.046	.17
Naked Eye Viewing	-.097	.34
Howard-Dolman Depth Discrimination		
NVG Viewing	+.501	2.00*
Naked Eye Viewing	+.413	1.57
Pursuit Rotor Eye-Hand Coordination	-.341	1.26
Choice Reaction Time Card Sort	+.167	.19
CFF Test of Visual Efficiency	-.256	.92

* $p < .05$ by a one-tail test.

Although only one statistically significant correlation emerged, six of the correlations are in the direction which would be expected if longer use resulted in poorer performance. The signs of the correlation coefficients indicate that with increasing NVG use acuity tended to decrease, the depth sensitivity threshold tended to increase, eye-hand coordination tended to decrease, and choice reaction time tended to increase. Only the correlation coefficients of use duration with CFF threshold did not have the expected sign.

While performance levels tended to show at least the expected directional patterns as NVG use duration increased, these same relationships might be expected between performance and age. Moreover, older pilots may tend to wear the NVG for longer periods on training missions,

as the younger, less experienced men may be expected to use the NVG for shorter periods. Indeed, the correlation between user age and use duration was significant ($r = +.59$, $df = 12$, $p < .05$). As the effects of these correlated factors on performance are confounded, partial correlations are necessary to determine the relationship of each factor independently with performance. No partial correlation approached significance, and the directional relationship observed previously between duration of NVG use and performance on each test was unchanged with age held constant. The age difference between experimental groups was small and not significant. Hence, none of the significant differences observed on the various tests can be attributed to age. The partial correlations of age and use duration with performance in the Postflight group, as well as the correlations between age and performance in the Baseline group, appear in Appendix D.

Summary and Conclusions

Comparisons of various performance indices of aviators who had worn the NVG for from one to four hours immediately prior to being tested with those of aviators who had no such pretest activities indicated the following:

1. Acuity and depth perception are both much better with the naked eye than with the NVG. Experience in properly adjusting and focusing the NVG seems necessary for optimal acuity through the device. Naked eye acuity may be degraded in a predictable manner if the NVG are used by unfatigued individuals, although after a period of NVG wear the relationship between naked eye acuity and NVG acuity may become unpredictable.
2. Eye-hand coordination seems to suffer after a period of NVG wear, yet with substantial practice on the task, performance approaches that of unfatigued individuals. Therefore, possibly no differences in eye-hand coordination on highly practiced tasks would be evident before and after lengthy NVG wear.
3. Choice reaction time appears unaffected from a period of NVG wear. There may, however, be a lack of response to errors committed in a choice reaction time task.
4. Critical flicker fusion thresholds are lower after a period of NVG wear, reflecting the steady physical exertion necessary in response to pressure and strain from the helmet/goggle configuration.

Correlations between duration of NVG wear and performance on various tests were weak, perhaps because of the small number of subjects tested and their restricted range of durations of NVG wear. For the most part, however, performance tended to suffer with increasing NVG wear. Older pilots may also tend to wear the NVG longer during training maneuvers, although the effects of age apparently do not alter the relationship between use duration and performance.

Chapter 4

USER EVALUATIONS OF MODIFICATIONS OF THE AN/PVS-5 & SPH-4 CONFIGURATION

As problems of discomfort and fatigue-related performance decrements from NVG use have become evident, an evaluation of possible remedies seems desirable. A structural way of solving the problems would be to modify the SPH-4 aviator helmet with which the NVG must be worn. This approach appears plausible in light of the large number of complaints from aviators regarding the shortcomings of the helmet/goggle interface.

An exploratory effort was therefore undertaken to determine the potential usefulness of considering structural modifications to the helmet/goggle configuration. Accordingly, two SPH-4 helmets, size "regular," were obtained and modified. The nature of the modifications and the rationale for each are outlined below.

Cutaway. The frontal lip of one helmet was modified by removing 7mm of fiberglass with a grinder. A local machine shop made this alteration such that the lip of the helmet tapered gradually upward from each side toward the middle. The rubber molding which covered the lip was replaced after grinding. The frontmost support for the inside headstraps was not disturbed, nor was the visor altered in any way.

Adjusting the NVG for comfort was rated as easier with the open-browed motorcycle crash helmet by respondents to the survey described in Chapter 2. An open-browed helmet allows the NVG to remain directly in front of the eyes without requiring helmet rotation to an abnormally rearward position on the head. The likelihood of increased comfort with the helmet resting in its proper position prompted the cutaway modification.

Counterweight. A weight was constructed to be attached to the rear of the helmet as an offset to the weight of the NVG in front. The counterweight consisted of lead automobile tire balancing bars glued and stitched to canvas. These bars seemed the most feasible weighting material to use, since their slight curvature allowed placement to conform to the curved rear surface of the SPH-4 helmet. The weight of the counterweight assembly (lead bars, canvas, twine, plastic border tape, eyelets, stove bolts and nuts) equalled that of an operational set of NVG--31 ounces. The counterweight was attached to the helmet with 1 1/4" by 1/4" stove bolts and nuts through holes drilled in the helmet, each 9cm from the bottom lip of the helmet in the rear, and 9cm from the vertical midline.

The asymmetrical distribution of weight on the head may be a primary cause of the problems observed. Army personnel have been shown to

be sensitive to changes in distributed weight on the head in the range under consideration.¹ The counterweight attached to the rear of the helmet counterbalances that of the NVG on the front, thus eliminating the asymmetry and relieving this source of difficulty.

Chincup. A chincup on a strap, designed primarily for use with a football helmet, was snapped onto the SPH-4 helmet. The snaps of the chincup, manufactured by Nokona, Inc., were identical to those of the regulation chinstrap of the SPH-4. The chincup and strap attachment were made of synthetic material, and the entire unit weighed one ounce.

A snugly fitting chincup on a strap provides extra support for stabilizing the SPH-4 helmet. With this added support the helmet may be positioned such that pressure on the face and/or nose from the weight of the NVG is relieved. The tendency noted in Chapter 2 for the NVG to slip down over the face, which also means slippage of the helmet on the head, would likewise be reduced when the chincup is used.

Design of the Evaluation

While alleviating both discomfort and fatigue would be the desired results of any structural modification to the helmet/goggle configuration, initial exploratory efforts would logically be concentrated on considerations of comfort. Estimated time to discomfort from NVG wear was shorter than estimated time to performance degradation due to fatigue, and such degradation is more reasonably viewed as a result of discomfort than vice versa. From a practical perspective, the effects of helmet/goggle modification on judgments of comfort are more readily determined than those on various types of performance. Accordingly, a number of aviators evaluated various modified helmet/goggle configurations in an exercise which was developed for this purpose. The evaluations were then analyzed to provide information regarding the desirability of each type of modification.

The Evaluation Exercise

An exercise, involving turning the head and neck in a particular pattern of movements at a specified rate, was developed in order that the evaluation of each modification would be based on the same motor activities.

¹R. D. Jones, B. M. Corona, P. H. Ellis, R. B. Randall, and H. A. Scheetz. *Perception of Symmetrically Distributed Weight on the Head*, Technical Note 4-72, US Army Human Engineering Laboratory, Aberdeen Research & Development Center, Aberdeen Proving Ground, Maryland, April 1972.

Apparatus. The two SPH-4 helmets and modifications were used, as well as a simulated set of NVG. The simulation consisted of the AN/PVS-5 face mask, cushion, and both top and side straps, with weights positioned to duplicate the exact balance and total weight of an operational unit. The weights were cast from lead, and included two large pieces and a small bar. The lead was glued and stitched to canvas. The canvas was then positioned over the top of the face mask, and bolted to the mask through eyelets in the canvas with 1" by 1/4" stove bolts and nuts. The bolt heads were prevented from slipping through the large holes through which they passed on either side of the face mask by large metal washers. The weights were kept precisely in place by twine which was sewn through the canvas and wrapped around the front of the face mask. The open front of the face mask was completely covered with plastic tape except for two small openings left for eye holes. The simulated set weighed exactly 31 ounces.

Upon one side of an 88" by 48" piece of corrugated cardboard were taped 1" by 1" paper squares, each bearing a different number from 1 through 7. The seven squares were arranged in a lazy-8 pattern, with the longer side of the cardboard rectangle resting horizontally (see Figure 4-1). The average distance between consecutively numbered squares was 33", with a range of 16" to 48".

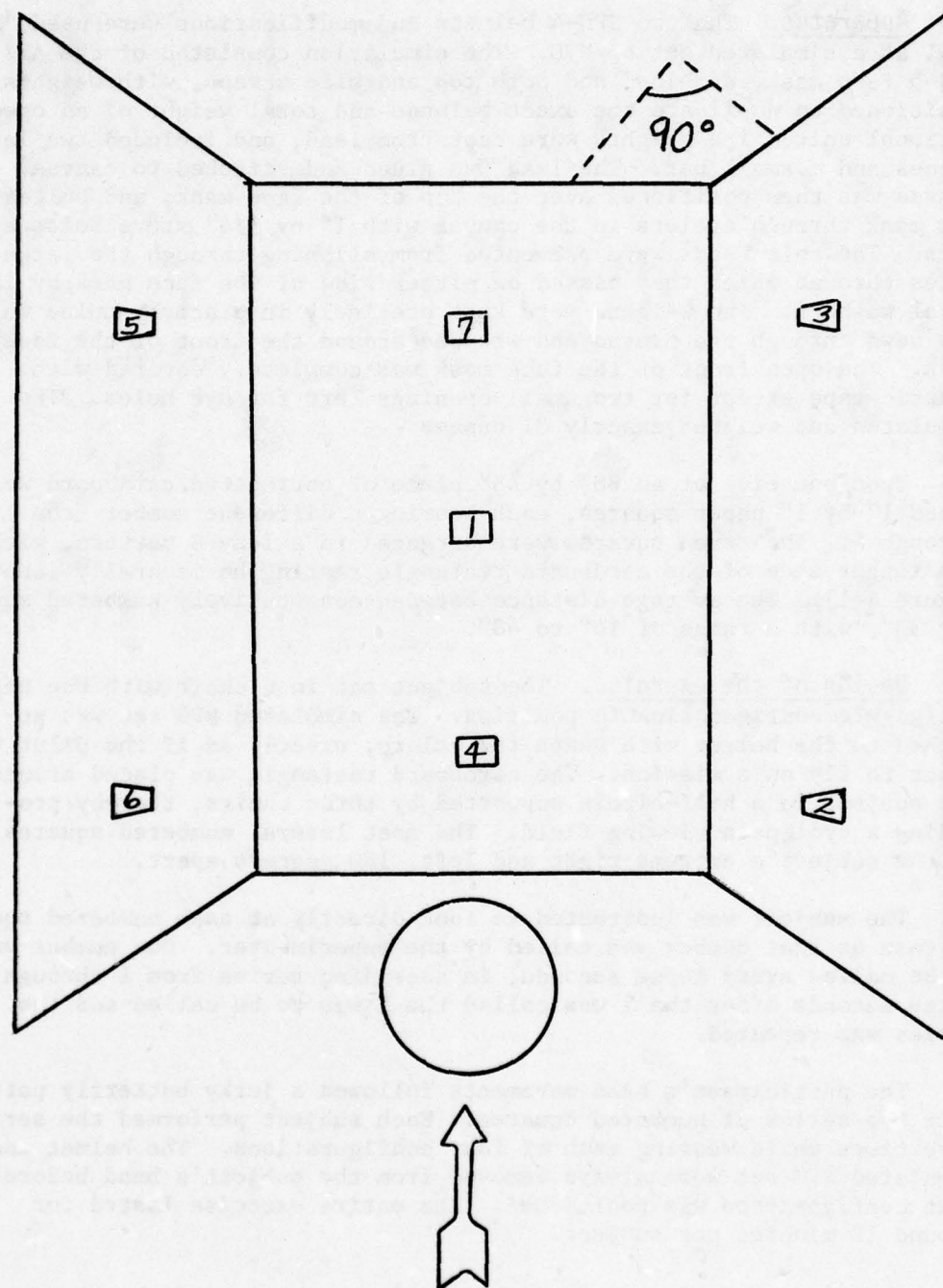
Design of the exercise. The subject sat in a chair with one helmet/goggle configuration in position. The simulated NVG set was attached to the helmet with snaps and velcro, exactly as if the pilot were about to fly on a mission. The cardboard rectangle was placed around the subject in a half-circle supported by three chairs, thereby providing a cyclopean viewing field. The most lateral numbered squares lay at the subject's extreme right and left, 180 degrees apart.

The subject was instructed to look directly at each numbered square in turn as that number was called by the experimenter. One number was to be called every three seconds, in ascending series from 1 through 7. Three seconds after the 7 was called the 1 was to be called and the series was repeated.

The participant's head movements followed a jerky butterfly pattern over the series of numbered squares. Each subject performed the series five times while wearing each of four configurations. The helmet and simulated NVG set were always removed from the subject's head before the next configuration was positioned. The entire exercise lasted for around 12 minutes per subject.

Procedure

Subjects were obtained from the Sixth US Air Cavalry Brigade (Air Combat) (6th ACCB), Fort Hood, Texas. All were aviators of rotary wing



Location of observer's chair

Figure 4-1. Cyclopean field for configuration evaluation exercise.

aircraft. The study was conducted using facilities furnished by the 6th ACCB, and was run from 23 January 1978 through 22 February 1978.

Two different combinations of helmet/goggle configurations were evaluated, the first by a group of 10 aviators, and the second by 20 aviators. Subjects performed the evaluation exercise individually. Each participant was first seated in the cardboard enclosure, and was given the instructions. After the subject had become familiar with the position of the numbers in the viewing field he exercised with each configuration in turn. The order in which the configurations were positioned for each subject varied in a 4 x 4 digram-balanced Latin square sequence.²

After the subject had completed all exercises he was given an evaluation form. The subject was reminded of the order in which he had exercised with the configurations, and was asked to arrange the labeled configurations in the rating sequence indicated by each of six indices on the form. Additional comments were invited on a separate page, and finally the participant was asked to complete a brief personal history outline. After all sections were completed, the subject was thanked for his participation and excused.

The instructions for the configuration comparison, along with the evaluation form completed by each subject, appear in Appendix E.

Results

Part I: First Configuration Combination

Configurations Under Evaluation

Four configurations were evaluated by the first sample of subjects. Each subject performed the exercise sequence while wearing the simulated NVG set and helmet in each of the following configurations:

- (1) Standard helmet
- (2) Counterweighted standard helmet
- (3) Cutaway helmet
- (4) Chincup with the standard helmet.

With (1), (2), and (3) above the regulation chinstrap was worn, while with (4) the chincup was substituted for the regulation chinstrap.

²W. A. Wagenaar. Note on the Construction of Digram-Balanced Latin Squares, *Psychological Bulletin*, 1969, 72, 384-386.

Description of the Sample

The configurations were evaluated by 10 aviators, all male personnel from the 6th ACCB, Fort Hood, Texas. All were warrant officers: 6 WO1s, 3 CW2s, and 1 CW3. Average age was 26 years, with all subjects aged 22 to 30 years. The group reported a mean of 6.18 years of service. Average career flight time was 1298.0 hours, and the mean amount of flying experience with the NVG was 6.95 hours.

Preference Ratings for the Configurations

The ordinal preference positions of each of the six indices were converted to the integers 1 through 4, with 1 representing the most favorable extreme for each index. Responses were tabulated by transcribing the relevant integer indicating the rated position of each configuration by each subject on each index. The mean ratings are given in Table 4-1. The statistical relationship of these ratings was analyzed by the nonparametric Friedman two-way analysis of variance by ranks. Table 4-2 shows the results of the analyses, as well as of the post hoc test devised by Nemenyi,³ as outlined by Hollander and Wolfe.⁴ The purpose of the post hoc comparisons was to determine the strength of differences between ratings of different pairs of configurations on each index.

As may be seen in the tables, the predominant differences occurred between the Standard helmet alone and various other configurations, with the Standard helmet being rated consistently lower. No strong pattern of preferences was noted between the Counterweight, Cutaway, and Chincup configurations. Indeed, if the Standard helmet alone is omitted from consideration, and the remaining helmets re-ranked from 1 through 3 for each subject on each index, only one statistically significant difference emerges. On the index concerning pressure on the face and/or nose ($X^2 = 6.2$, $df = 3$, $p < .05$), the post hoc Nemenyi test indicated that the Counterweight was favored over the Chincup.

Additional comments were made by several evaluators. One aviator observed that the Chincup configuration might interfere with verbal communication. Another subject felt that the Counterweight configuration might induce fatigue with extended use due to the added weight. Six of the 10 participants mentioned that the counterweights should be added to the Cutaway helmet, or that other combinations of the modifications should be evaluated.

³P. Nemenyi. "Distribution-free Multiple Comparisons," Doctoral Dissertation, Princeton University, 1963.

⁴M. Hollander and D. A. Wolfe. *Nonparametric Statistical Methods*, New York: John Wiley & Sons, 1973.

Table 4-1. Mean Rating for Each Configuration on Each Index
for the First Configuration Combination
(1 = most favorable)

<u>Index</u>	<u>Configuration</u>			
	<u>Stand- ard</u>	<u>Counter- weight</u>	<u>Cutaway</u>	<u>Chin- cup</u>
1. Pressure exerted on cheek bones and/or nose	3.5	1.6	2.0	2.9
2. Strain placed on neck muscles	3.5	2.4	2.2	1.9
3. Tendency of goggles to slip down on the face	3.6	2.0	2.1	2.3
4. Length of time to discomfort	3.7	1.9	1.9	2.5
5. Ease allowed in turning the head	3.2	2.1	2.1	2.6
6. Preference for extended night missions	3.7	2.1	1.8	2.4

Table 4-2. Statistical Differences Between Configurations on Each Index with Significant Differences Between Pairs of Configurations Indicated
(First Configuration Combination)

<u>Index</u>	χ^2 ($df = 3$)	<u>Probability</u>	Differences Between Pairs (">" between configuration labels means "rated more favorably than")
1. Pressure exerted on cheek bones and/or nose	13.32	$p < .01$	Counterweight > Standard ($p < .05$) Cutaway > Standard ($p > .05$)
2. Strain placed on neck muscles	8.76	$p < .05$	Chincup > Standard ($p < .05$)
3. Tendency of goggles to slip down on the face	9.96	$p < .02$	Counterweight > Standard ($p < .05$) Cutaway > Standard ($p < .05$)
4. Length of time to discomfort	12.96	$p < .01$	Counterweight > Standard ($p < .01$) Cutaway > Standard ($p < .01$)
5. Ease allowed in turning the head	4.92	$p > .10$	No significant differences
6. Preference for extended night missions	12.60	$p < .01$	Cutaway > Standard ($p < .01$) Counterweight > Standard ($p < .05$)

Because no clear-cut pattern of preferences was evident with this combination of configurations (other than the fact that the Standard helmet alone was particularly disfavored), another combination of configurations which omitted the Standard helmet alone and combined modifications was evaluated by an additional sample of subjects.

Part II: Second Configuration Combination

Configurations Under Evaluation

Four configurations were evaluated by the second sample of subjects. Each subject performed the exercise sequence while wearing the simulated NVG with the helmet in each of the following configurations:

- (1) Cutaway
- (2) Counterweight with Cutaway
- (3) Chincup with Cutaway
- (4) Chincup with Standard

With (1) and (2) above the regulation chinstrap was worn, while with (3) and (4) the chincup was substituted for the regulation chinstrap.

Description of the Sample

The configurations were evaluated by 20 aviators, all male personnel from the 6th ACCB, Fort Hood, Texas. All were warrant officers: 6 WO1s, 13 CW2s, and 1 CW3. Average age was 28.35 years, with a range of 20 to 35 years. A mean of 7.39 years of service was reported by the group. Average career flight time was 1901.50 hours, and the mean amount of flying experience with the NVG was 1.98 hours.

Preference Ratings for the Configurations

The statistical techniques used to analyze the second configuration combination were identical to those used to analyze the first configuration combination. The mean ratings for the second combination are given in Table 4-3. Table 4-4 shows the result of the Friedman two-way analysis of variance by rank with this data, as well as of the post hoc Nemerni test.

From the tables it is clear that the Counterweight with Cutaway and Chincup with Cutaway were consistently favored over the other two configurations. Although no statistical difference between the former was observed on any index, the Counterweight with Cutaway was statistically favored a total of nine times, while the Chincup with Cutaway was statistically favored only six times total. Moreover, the statistical significance levels tended to be somewhat stronger for the Counterweight with Cutaway.

Table 4-3. Mean Rating for Each Configuration on Each Index
for the Second Configuration Combination
(1 = most favorable)

<u>Index</u>	<u>Configuration</u>		
	<u>Cut- away</u>	<u>Counterweight/ Cutaway</u>	<u>Chincup/ Cutaway</u>
1. Pressure exerted on cheek bones and/or nose	3.20	1.45	2.45
2. Strain placed on neck muscles	2.95	2.40	1.95
3. Tendency of goggles to slip down on the face	3.20	1.85	1.95
4. Length of time to discomfort	3.05	1.90	1.90
5. Ease allowed in turning the head	2.95	1.95	2.10
6. Preference for extended night missions	3.10	1.80	2.00
			3.15
			3.00
			3.10

Table 4-4. Statistical Differences Between Configurations on Each Index, with Significant Differences Between Pairs of Configurations Indicated (Second Configuration Combination)

Index	χ^2 (df = 3)	Probability	Differences Between Pairs (">" between configuration labels means "rated more favorably than")	
			Counterweight/Cutaway > Cutaway (p < .01)	Counterweight/Cutaway > Chincup and Standard (p < .01)
1. Pressure exerted on cheek bones and/or nose	21.06	p < .001		
2. Strain placed on neck muscles	6.66	.05 < p < .10	No significant differences	
3. Tendency of goggles to slip down on the face	17.58	p < .001	Counterweight/Cutaway > Cutaway (p < .01) Counterweight/Cutaway > Chincup/Standard (p < .05) Chincup/Cutaway > Cutaway (p < .05) Chincup/Cutaway > Chincup and Standard (p < .05)	
4. Length of time to discomfort	17.34	p < .001	Counterweight/Cutaway > Cutaway (p < .05) Counterweight/Cutaway > Chincup and Standard (p < .05) Chincup/Cutaway > Cutaway (p < .05) Chincup/Cutaway > Chincup and Standard (p < .05)	
5. Ease allowed in turning the head	10.98	p < .02	Counterweight/Cutaway > Chincup/Standard (p < .05)	

-----cont'd-----

<u>Index</u>	χ^2 (df = 3)	Probability	Differences Between Pairs (">" between configuration labels means "rated more favorably than")
6. Preference for extended night missions	17.52	$p < .001$	Counterweight/Cutaway > Cutaway ($p < .01$) Counterweight/Cutaway > Chincup and Standard ($p < .01$) Chincup/Cutaway > Cutaway ($p < .05$) Chincup/Cutaway > Chincup and Standard ($p < .05$)

Additional comments were made by some subjects. The observation was again made that the Chincup might interfere with verbal communication. Three aviators mentioned that the Counterweight might become tiring after lengthy use. One aviator was concerned about safety considerations in relation to the Counterweight, and three subjects suggested that the helmet be counterbalanced, but not by as much as the total weight of the NVG. One subject was of the opinion that one pound would be sufficient. Two participants felt that the Chincup would need to be tailored for each individual, and one subject suggested that a combination of all modifications be evaluated.

Summary and Conclusions

The standard SPH-4 without modification was rated very unfavorably for wear with the NVG. Cutting back the frontal lip of the helmet to allow it to rest in its normal position while being worn with the NVG seemed to provide greater comfort, especially when a counterweight or a chincup was used. However, the additional modification could pose new difficulties; the chincup may interfere with speech, and the counterweight might be fatiguing with lengthy wear as well as posing a safety problem due to the increased weight.

Other modifications of the SPH-4 helmet might be developed and evaluated, or some minor modification could be made to the NVG face mask. Ideally, modified configurations would be worn by the pilot during actual helicopter flight. Tests which had indicated a performance decrement with the unmodified configuration could be re-administered to pilots upon their completion of extended flights with the modified set to determine the extent to which fatigue-related problems had been reduced or eliminated.

Chapter 5

RECAPITULATION AND CONCLUDING REMARKS

A primary purpose of this investigation was to determine, from questionnaires, tests, and ratings, the nature and scope of fatigue problems related to AN/PVS-5 NVG wear. It was found that while the NVG are very useful, discomfort and fatigue resulting from NVG wear are reflected not only in complaints from the users, but also in the degradation of certain performance skills. Remedies in the form of modifications to the SPH-4 helmet/NVG configuration were identified.

No report of other investigations of fatigue effects resulting from use of the NVG has been located. Further research is therefore badly needed. The effects of fatigue from NVG wear on other subsets of skills involved in piloting should be determined. NVG fatigue effects in other users, such as tank crews, in relation to surveillance and equipment operation need to be examined. Additional work is needed on developing ways of reducing discomfort and fatigue from the helmet/goggle configuration. As well as physical modifications to the equipment, exercises performed by the users to strengthen muscles and build stamina should be considered.

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APPENDIX A

Instructions and Questionnaire for AN/PVS-5 NVG User Ratings

Instructions for AN/PVS-5 Questionnaire

The Human Resources Research Organization (HumRRO) has been asked by the 6th Brigade (Air Combat) to investigate complaints related to the wearing of the AN/PVS-5 night vision goggles. The first step in this investigation is to determine the scope and extent of the problem. Accordingly, the enclosed questionnaire was developed to allow HumRRO to collect information from the users of the AN/PVS-5 goggles. This information will provide a basis for recommendations for improving the goggles to optimize their effectiveness in night flight. Please consider all of the items on the questionnaire carefully and respond as honestly and completely as possible. Your input will have great value in determining the direction the investigation must take.

Thank you,

HumRRO Research Staff

POST-MISSION AN/PVS-5 QUESTIONNAIRE

Name _____ Date _____
 (Last) (First) (MI)

MOS _____ Age _____

Years Service _____

Career Total Hours of Flight Time _____

1a. Approximately how long was the flight you just returned from?

1b. Approximately how long did you wear the AN/PVS-5 goggles on this flight? _____

1c. Aircraft flown on this flight. _____

2. Approximately how many total hours have you flown with the AN/PVS-5 goggles? _____

3. Which of the following maneuvers or tasks were performed wearing the AN/PVS-5 goggles during the flight you just returned from? Check all that apply.

Maneuver/ Task	Check if performed with AN/PVS-5 goggles	Check if task difficulty is greater or less with AN/PVS-5 goggles than with naked eye		
		Less Difficult	About the Same	More Difficult
Take-off to hover	_____	_____	_____	_____
Landing from hover	_____	_____	_____	_____
Normal take-off	_____	_____	_____	_____
Normal approach	_____	_____	_____	_____
Steep take-off	_____	_____	_____	_____
Steep approach	_____	_____	_____	_____
Slope operations	_____	_____	_____	_____
Confined area ops	_____	_____	_____	_____

Maneuver/ Task	Check if performed with <u>AN/PVS-5 goggles</u>	Check if task difficulty is greater or less with AN/PVS-5 goggles than with naked eye		
		<u>Less Difficult</u>	<u>About the Same</u>	<u>More Difficult</u>
Pinnacle ops	—	—	—	—
Flight above 200' AGL	—	—	—	—
Low level flight	—	—	—	—
Contour flight	—	—	—	—
NOE flight	—	—	—	—
NOE quick stop	—	—	—	—
NOE down-wind T/O	—	—	—	—
NOE down-wind landing	—	—	—	—
Inadvertant IMC	—	—	—	—
ITO	—	—	—	—
Inst app (non-prec)	—	—	—	—
Sling load ops	—	—	—	—
Hovering auto 5'	—	—	—	—
Hovering auto 15'	—	—	—	—
L/L auto 50'/50k	—	—	—	—
L/L auto 50'/80-90k	—	—	—	—
L/L auto 50'/130k	—	—	—	—
Standard auto	—	—	—	—
Stan auto w/turn	—	—	—	—
Anti-torque fail	—	—	—	—
Hydraulic failure	—	—	—	—
Forced landing	—	—	—	—
Route recon	—	—	—	—

<u>Maneuver/ Task</u>	<u>Check if performed with AN/PVS-5 goggles</u>	<u>Check if task difficulty is greater or less with AN/PVS-5 goggles than with naked eye</u>		
		<u>Less Difficult</u>	<u>About the Same</u>	<u>More Difficult</u>
Zone recon	—	—	—	—
Area security	—	—	—	—
Screen	—	—	—	—
Guard	—	—	—	—
Covering force	—	—	—	—
Economy of force	—	—	—	—
Raid	—	—	—	—
Radiological survey	—	—	—	—
Rappelling	—	—	—	—
Insert/extract IID	—	—	—	—
Mine dispensing	—	—	—	—

4. Did you experience in difficulty in wearing the AN/PVS-5 goggles?

Yes —

No —

5. If you responded Yes to Item 4, did you experience any of the following while wearing the AN/PVS-5 goggles? Check all that apply.

a. Pressure on bridge of nose —

b. Pressure on cheek bones —

c. Fatigue on neck muscles —

d. Fatigue of back muscles —

e. Headaches —

f. Disorientation —

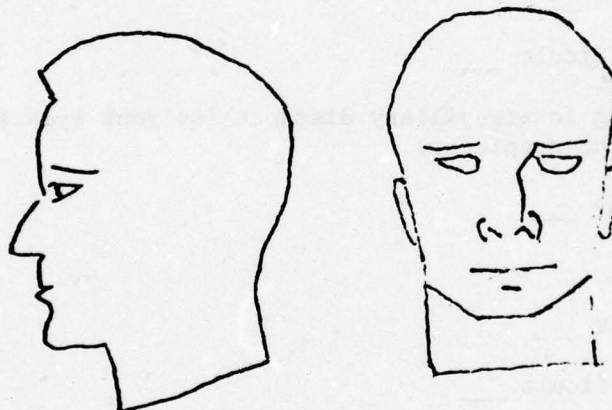
g. Vertigo —

h. Dizziness ____

i. Eyestrain ____

j. Other (describe) _____

6. If you checked a or b above, please indicate on the drawing below, approximately where the pressure occurred:



- 7a. How long did you wear the AN/PVS-5 goggles before discomfort became apparent? _____ minutes (estimate)

- 7b. With the current goggle design, please estimate how long you could wear them before discomfort began degrading your performance.

8. The following tasks relate to the use of the AN/PVS-5 goggles. Please rate each of these in terms of the relative ease of accomplishment:

a. Placing goggles on your head by attaching them to helmet

Very easy ____

Easy ____

Difficult ____

Very difficult ____

b. Adjusting goggles and helmet for comfortable wearing

Very easy ____

Easy ____

Difficult ____

Very difficult ____

c. Adjusting interpupillary distance (so your eyes are centered behind the eyepieces)

Very easy ____

Easy ____

Difficult ____

Very difficult ____

d. Diopter adjustment (adjust to your eyes)

Very easy ____

Easy ____

Difficult ____

Very difficult ____

e. Focusing

Very easy ____

Easy ____

Difficult ____

Very difficult ____

9. List any other problems you have had in using the AN/PVS-5 goggles:

APPENDIX B

Personal History and Subjects' Overview

Subject No. _____ Condition _____

AN/PVS-5 Visual Performance Battery

Name _____ Date _____
(Last) (First) (MI)

Rank _____ Military Unit _____ MOS _____

Age _____ Years Service _____

Career Total Hours Flight Time _____

1. Approximately how long did you wear the AN/PVS-5 goggles immediately prior to arriving here today?
2. Approximately how many total hours have you worn the AN/PVS-5 goggles?

Subject No. _____

Condition _____

Name _____

Date _____

Time _____ am/pm

AN/PVS-5 PERFORMANCE BATTERY - INSTRUCTIONS FOR PARTICIPANTS

- I. Today you will be performing a series of visual tasks that should require about one hour to complete. The purpose of these tasks is to provide information regarding soldiers' ability to perform various visually guided functions under specific conditions. Your patterns of performance will help the Army to make decisions on equipment which will benefit all users. Your best effort is, therefore, essential. However, information concerning your performance will not become part of your record and will not be used in whole or in part in making any determination about you personally.
- II. Position and adjust goggles and helmet for comfort and visual efficiency. After the lights are lowered, go to the following stations in this order:

1st _____

2nd _____

After completing the three tests above, remove the goggles and helmet. When the lights come on, proceed to the following stations in this order:

1st _____

2nd _____

3rd _____

4th _____

5th _____

APPENDIX C

Instructions and Answer Sheets for AN/PVS-5 Performance Test Battery

Instructions For Visual Acuity

Goggled

You are about to look at a chart composed of a number of circles, each of which has two breaks on it. These breaks result in a segment of the circle which is approximately a quarter of its circumference being detached from the remaining three quarters. Here on the legend you see that the first circle has the detached quadrant in the "down" position, the second "up," the next "right," the last "left." Then on the bottom line, first "lower right," "lower left," "upper right," then "upper left." Each circle on the chart will have a detached quadrant on one of these eight positions. Do you understand the eight possible positions of the detached quadrant?

All right, stand with your toes touching this line and tell me the position of the detached quadrant for each of the six circles above the red line. Start at the top, and go from left to right on each line.

Here's another chart with ten rows of circles, nine circles on a row. The leftmost circle on each row is largest, and the rightmost is smallest. With your toes on the line, slowly tell me the position of the detached quadrant for each circle on the chart. Start with the leftmost circle on the top row, move to the right through all the circles on that row. Then go to the second row, and so on for all ten rows. If you are not sure of the position on a circle, give me your best judgment.

Are there any questions?

Let's begin.

Ungoggled

Once again I want you to tell me the position of the detached quadrant of some circles. Here are the eight possible directions again on the legend. Stand with your toes on the line, and beginning with the first row above the blue line on the chart, tell me the position of the detached segment on each circle, moving from the leftmost circle to the rightmost. Then, move to the next lower row below the blue line, and do the same for it and the bottom two rows. If you are not sure of the quadrant's position on a circle, give me your best judgment.

Let's start now.

Subject No. _____

Condition _____

DOUBLE BROKEN RING ACUITY TEST

Name _____ Date _____ Time _____ am/pm

Practice Trials: UR UL LR LR UR LL

Goggled

Trial No.

1	<u>UR</u>	<u>U</u>	<u>LR</u>	<u>U</u>	<u>UL</u>	<u>UR</u>	<u>U</u>	<u>LL</u>	<u>U</u>
2	<u>L</u>	<u>UL</u>	<u>L</u>	<u>L</u>	<u>UR</u>	<u>LL</u>	<u>LL</u>	<u>D</u>	<u>L</u>
3	<u>LL</u>	<u>D</u>	<u>UL</u>	<u>R</u>	<u>L</u>	<u>U</u>	<u>L</u>	<u>U</u>	<u>R</u>
4	<u>LR</u>	<u>R</u>	<u>LR</u>	<u>UR</u>	<u>UL</u>	<u>UL</u>	<u>LR</u>	<u>LR</u>	<u>UR</u>
5	<u>UL</u>	<u>LR</u>	<u>D</u>	<u>LL</u>	<u>LR</u>	<u>R</u>	<u>R</u>	<u>R</u>	<u>D</u>
6	<u>D</u>	<u>U</u>	<u>U</u>	<u>LL</u>	<u>D</u>	<u>UL</u>	<u>L</u>	<u>UR</u>	<u>U</u>
7	<u>LL</u>	<u>UL</u>	<u>UL</u>	<u>UR</u>	<u>LL</u>	<u>LR</u>	<u>UR</u>	<u>L</u>	<u>LL</u>
8	<u>UR</u>	<u>L</u>	<u>R</u>	<u>U</u>	<u>LR</u>	<u>L</u>	<u>LL</u>	<u>U</u>	<u>D</u>
9	<u>U</u>	<u>R</u>	<u>LR</u>	<u>D</u>	<u>R</u>	<u>R</u>	<u>LR</u>	<u>UL</u>	<u>R</u>
10	<u>L</u>	<u>D</u>	<u>UR</u>	<u>R</u>	<u>D</u>	<u>U</u>	<u>U</u>	<u>R</u>	<u>UL</u>

P(c) _____

Condition _____

Naked Eye

30:	\overline{LL}	\overline{D}	\overline{UL}	\overline{L}							P(c) _____
25:	\overline{D}	\overline{LR}	\overline{U}	\overline{UR}							P(c) _____
20:	\overline{R}	\overline{LR}	\overline{U}	\overline{UR}	\overline{D}	\overline{LL}	\overline{R}	\overline{UL}	\overline{D}	\overline{LR}	P(c) _____
17 1/2:	\overline{LL}	\overline{L}	\overline{UL}	\overline{D}	\overline{LR}						P(c) _____
15:	\overline{L}	\overline{LR}	\overline{U}	\overline{LL}	\overline{R}						P(c) _____
12 1/2:	\overline{LR}	\overline{D}	\overline{LL}	\overline{L}	\overline{UL}	\overline{R}					P(c) _____
10:	\overline{UR}	\overline{R}	\overline{D}	\overline{L}	\overline{LR}	\overline{U}					P(c) _____

Instructions For Depth Perception

Goggled

Inside this box are two white sticks standing up horizontally. These sticks are attached to blocks that can be pulled back and forth with this rope. What you will be trying to do is to align these sticks so that they are side by side, both at the same distance from you. You will be sitting way back here and looking into the box through this window in the front.

First, I will pull the rope to get the sticks at different distances from you. Then, I will hand you the rope and you will adjust the sticks until they are even. If you pull the rope on the left side, the right stick will move forward, while at the same time the left one moves back. If you pull it on the right side, then the left stick will move forward while the right stick moves back. Take as much time as you need to get the sticks lined up. After you have the sticks where you think they should be, say "okay" and I will look inside the box to see whether you were off, and if so by how much. Then I will lower the top of the box, pull the rope again to misalign the sticks, and have you line them up again.

Are there any questions?

I'm going to let you try it a couple of times for practice and then you will do it several times more for a performance measure.

Ready?

Ungoggled

This is the same stick alignment task as you performed before. Once again I want you to try to line the sticks up side by side, equidistant from you. Do this once now for practice, and then we will have some performance runs.

Subject No. _____

Condition _____

DEPTH PERCEPTION

Name _____ Date _____ Time _____ am/pm

Practice:

Trial No.	L	R
1 (G)	_____	_____
2 (G)	_____	_____
3 (NE)	_____	_____

Trial No.	Goggled		Naked Eye	
	L	R	L	R
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____
4	_____	_____	_____	_____
5	_____	_____	_____	_____

Mean	_____	_____	_____	_____
Mean Error (Absolute)	_____	_____	_____	_____
SD Absolute Error	_____	_____	_____	_____
SD Real Error	_____	_____	_____	_____

Instructions For Pursuit Rotor

The object in this task is to keep this black stylus directly over the rotating light. You will notice that the speed at which the light seems to move around the triangular track is not constant--it speeds up while going around the corners of the triangle.

First, I want you to put the stylus in the center of the triangle like this. When the light comes on, immediately move the stylus to a position over the light, then move the stylus around the track like this, always trying to keep the stylus directly over the light. Keep the tip of the stylus pressed against the glass at all times. Twenty seconds after the light comes on it will go off, and at that time I want you to immediately move the stylus back to the center of the triangle like this so you will be ready for the next run.

Do you have any questions?

Now, I'm going to give you a couple of practice runs, after which you will have five performance runs. I will be keeping track of the time out of 20 seconds that you were able to stay on target for each run.

Let's try the first practice run now.

Subject No. _____

Condition _____

PURSUIT ROTOR

Name _____ Date _____ Time _____ am/pm

Time on Target (sec) Out of (sec) Z

Practice:

Trial No.

1

2

Criterion:

Trial No.

1

2

3

4

5

Mean

SD

Median

Instructions For Card Sort

What I have here is a deck of 36 cards. Upon each card are two lines, and there are four combinations of line lengths: either both long, like this; or both short, like this; or the left line long and the right line short, like this. You are going to be sorting decks into four piles, one for each line length combination. I am going to measure the amount of time it takes you to sort a deck. So, sort as fast as you can, but try to make no errors at all. If you accidentally put a card into a pile where it shouldn't be, leave it there, but try to be more careful after that.

First, I will put down four cards, one of each length combination, on the table in front of you. I will then hand you a deck of cards with a numbered card on top. When you are ready to begin, toss the numbered card onto the table like this, and then immediately sort the cards, putting each combination in a stack over the first one of that type which I have laid down in front of you. When you drop the white card, I will start a stopwatch. When you put the last card of the deck into its proper stack, I will stop the stopwatch and record how long you took on that sort. Always keep the black edge of the deck facing toward you.

Are there any questions?

First, we will do a few practice sorts so that you can get the hang of it. Then you will do several performance sorts.

Let's try the first one now.

Subject No. _____

Condition _____

CHOICE REACTION TIME CARD SORT

Name _____

Date _____

Time _____ am/pm

Practice:

Trial No.	Time (sec)	Errors
1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____

Criterion:

Naked Eye

Trial No.		
1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____
5	_____	_____
Mean	_____	_____
SD	_____	_____
Median	_____	

Instructions For Flicker Fusion

Inside this box is a light which can be adjusted to flicker. Sometimes I will at first adjust the light to flicker. Then I will make the flicker more and more rapid. I want you to say "stop" immediately when the flicker disappears. Sometimes, however, I will at first adjust the light to be on continuously. Then I will start to introduce a very rapid flicker. In this instance, say "stop" immediately when you notice the rapid flicker.

Although the light is not flickering, occasionally it may seem to slowly pulse brighter and dimmer. Do not confuse this with a flicker. The flicker you will be watching for to start or stop will be very rapid.

Are there any questions?

First, I will give you some practice runs. Then you will do several performance runs.

Let's try the first practice run now.

Subject No. _____

Condition _____

CRITICAL FLICKER FREQUENCY DETERMINATION

Name _____ Date _____ Time _____ am/pm

Practice:

Trial No.	Condition*	$f (H_z)$
1	A	_____
2	D	_____
3	A	_____
4	D	_____

Criterion:

1	A	_____
2	A	_____
3	D	_____
4	A	_____
5	D	_____
6	D	_____
7	D	_____
8	A	_____
9	A	_____
10	D	_____

*A = Ascending, D = Descending

A: \bar{x} _____ SD _____

D: \bar{x} _____ SD _____

All: \bar{x} _____ SD _____

APPENDIX D

Correlations Involving Age and Performance Levels for the Postflight Group

I. Partial Correlations of Age or Duration of NVG Use with Performance Levels While Holding the Other Factor Constant for the Postflight Group

Test	r Duration of Use Holding Age Constant	r Age of Holding Dura- tion of Use Constant
Double Broken Ring Acuity		
NVG Viewing	-.11	+.16
Naked Eye Viewing	-.27	+.19
Howard-Dolman Depth Discrimination		
NVG Viewing	+.37	+.13
Naked Eye Viewing	+.40	-.10
Pursuit Rotor Eye-Hand Coordination	-.10	-.34
Choice Reaction Time Card Sort	+.10	+.07
CFF Test of Visual Efficiency	-.15	-.11

II. Correlation of Age with Performance Levels for the Baseline Group

Test	r
Double Broken Ring Acuity	
NVG Viewing	-.09
Naked Eye Viewing	-.11

Test	<i>r</i>
Howard-Dolman Depth Discrimination	
NVG Viewing	+.04
Naked Eye Viewing	-.20
Pursuit Rotor Eye-Hand Coordination	-.46*
Choice Reaction Time Card Sort	+.05
CFF Test of Visual Efficiency	.00

$\overline{*p < .05}$

APPENDIX E

Instructions and Evaluation Forms For AN/PVS-5 & SPH-4 Configuration Comparison

Instructions For Configuration Comparison

You are about to do some head-turning exercises while wearing different configurations of the AN/PVS-5 Night Vision Goggles and the SPH-4 helmet.

As you sit in this cardboard cubicle, notice the numbered tags on the walls. After positioning a configuration, you will exercise by looking directly at each number in turn as I call that number. The numbers will be called in ascending order from 1 through 7, one number every three seconds. After 7 is called, 1 will be called again, and the sequence will be repeated. You will perform the sequence five times for each configuration, and there will be four configurations. I am having you exercise this way so that all evaluations will be based on the same pattern of head movements.

During the exercises, note especially how each configuration makes your face and neck muscles feel, how well the goggles remain in position, and the ease with which each configuration allow you to turn your head.

Now, before you begin the exercises, I will call out several sequences of the numbers, and you find the proper number as each is called. The location of each number will thus become familiar to you. Then, during the exercises you can concentrate on how each configuration feels rather than on finding the correct number.

Subject No. _____

AN/PVS-5 & SPH-4 CONFIGURATION COMPARISON

Name _____ Date _____
(last) (first) (MI)

Rank _____ Military Unit _____ MOS _____

Age _____ Years Service _____

Career Total Hours Flight Time _____

Approximate total hours you have worn the AN/PVS-5 goggles _____

AN/PVS-5 & SPH-4 CONFIGURATION COMPARISON

The various helmet goggle configurations have been labeled A, B, C, and D in the sequence in which you used them in the preceding exercise. For each judgment below, arrange the configurations in the order indicated.

1. Order the configurations according to the pressure exerted on the cheek bones and/or nose:

most pressure

least pressure

2. Order the configurations according to the strain placed on neck muscles:

most strain

least strain

3. Order the configurations according to the degree to which goggles tended to slip down on your face:

slipped the least

slipped the most

4. Order the configurations according to the length of time they could be worn before discomfort would occur:

first to cause
discomfort

last to cause
discomfort

5. Order the configurations according to the overall ease with which they allowed you to turn your head:

most ease

least ease

6. Order the configurations according to your preference for use on extended night missions:

most preferred

least preferred

7. Make additional comments if you wish regarding the configurations: